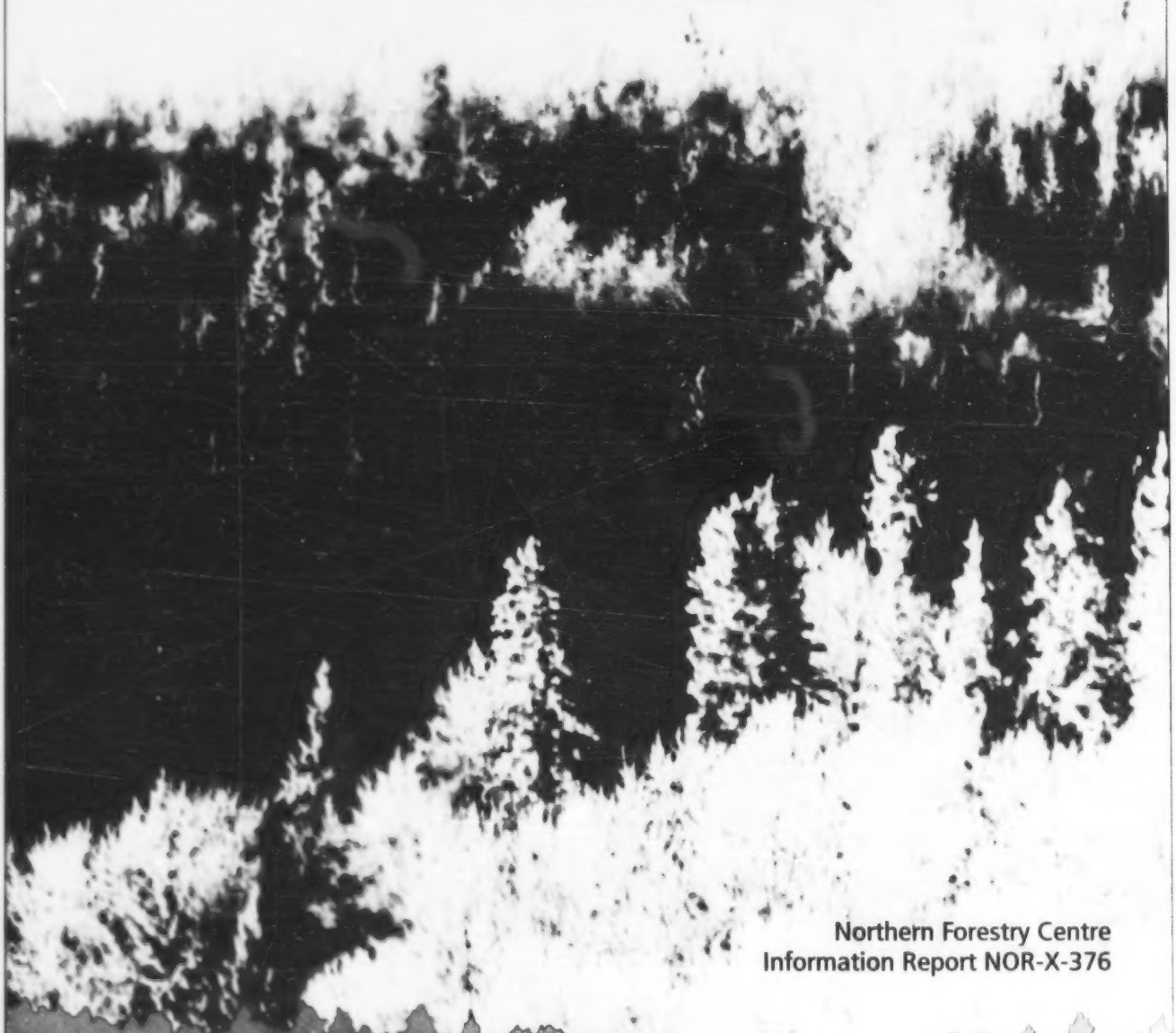
Social sciences and Canadian forestry: an annotated bibliography (1978–1998)

A. Ghebremichael and H. Mackenzie



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The Canadian Forest Service's Northern Forestry Centre is responsible for fulfilling the federal role in forestry research and technology transfer in Alberta, Saskatchewan, Manitoba, Nunavut, and the Northwest Territories. The main objectives are research in support of improved forest management for the economic, social, and environmental benefit of all Canadians.

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Le Centre de foresterie du Nord constitue l'un des cinq établissements du Service canadien des forêts, dont l'administration centrale est à Ottawa (Ontario).

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ABSTRACT

An extensive literature survey was conducted to identify research related to the socioeconomic aspects of forestry in Canada and elsewhere. A multitude of scientific journals, Web sites, databases, and professional reports were reviewed. The result is a bibliography of more than 200 documents. The references were classified according to the science and technology networks of the Canadian Forest Service and are presented here as an annotated bibliography.

RÉSUMÉ

Il s'agit d'un vaste travail de recensement des travaux de recherche qui ont été faits sur les aspects socio-économiques de l'exploitation forestière au Canada et ailleurs dans le monde. L'ouvrage porte sur plus de 200 documents : revues scientifiques, sites web, bases de données, rapports techniques, etc. Les documents recensés sont classés selon les réseaux scientifiques et technologiques du Service canadien des forêts et sont présentés sous forme de bibliographie annotée.

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Note

The exclusion of certain manufactured goods does not necessarily imply disapproval nor does the the mention of other products necessarily imply endorsement by Natural Resources Canada.

INTRODUCTION

Socioeconomic forestry research in the Canadian Forest Service (CFS) has declined since the 1970s. However, the issues addressed by socioeconomic forestry research, such as the development and sustainability of community-based economies, the efficient allocation of the land base among its alternative uses, and concerns about environmental quality, continue to present challenges to policymakers and forest managers. To highlight how socioeconomic research relates to the objectives of the science and technology networks of the CFS, this paper presents an annotated bibliography of the recent literature in this area from Canada and elsewhere.

LITERATURE SEARCH

An extensive literature survey was done to assess the extent of socioeconomic research related to each of the nine biological science and technology (S&T) networks of the CFS. Scientific journals, professional reports, and various Web sites were surveyed. To make sure that we did not miss important publications relevant to any S&T network, all network managers were formally requested to direct us to sources that we might have missed. The result of this effort is a database of more than 200 documents.Our sources are categorized as journals, Web sites, and other sources.

Journals

The following journals were surveyed (issue numbers are given in parentheses; if no issue number is given, all issues in the volume were consulted):

Canadian Journal of Agricultural Economics, vols. 43, 44(1, 2, 3), 45(1)

Canadian Journal of Forest Research, vols. 10-26

Climate Change, vols. 3-33

Ecological Economics, vols. 1-20, 21(2)

Forest Ecology and Management, vols. 3-39, 93(1, 2, 3), 95(1)

Forest Science, vols. 26-42, 43(1, 2)

Forestry, vols. 53-69, 70(1, 2, 3)

Forestry Chronicle, vols. 56-71

Journal of Biogeography, vol. 22

Journal of Environmental Economics and Management, vols. 14-25, 26(1, 2), 27-33

Journal of Forest Economics, vols. 1-2, 3(1, 2), 4

Journal of Forest Research, vols. 1(1, 2, 3, 4), 2(1, 2)

Journal of Forestry, vols. 78-94

Journal of Sustainable Forestry, vols. 1-3

Northern Journal of Applied Forestry, vols. 1-10, 13(4), 14(1, 2)

Quarterly Journal of Forestry, vols. 73-90, 91(1, 2, 3)

Scandinavian Journal of Forest Research, vols. 1-11, 12(1, 2)

Silva Fenica, vols. 14-29, 31(1, 2)

Technological Forecasting and Social Change, vol. 50

Western Journal of Applied Forestry, vols. 7-10, 12(2)

Web Sites

Databases at the following Web sites were surveyed for publications of relevance to this bibliography:

University of Minnesota AgEcon Search database of research in agricultural and applied economics, <http://agecon.lib.umn.edu/>

<http://www.epa.gov/docs/oppe/eaed/eedhmpg.htm>

<http://www.orst.edu/dept/ag_resrc_econ/biodiv/biblio.htm>

World Resources Institute, Washington, D.C., <http://www.wri.org/>

World Bank publications,
<http://www.worldbank.org/publication/index.htm>

Ideal online library, Harcourt, Inc., <http://www.idealibrary.com>

Other Sources

The WinSPIRS (Windows [Win] version of a Silver Platter Information Retrieval System [SPIRS]) version 2.0 database was consulted, and the following sections of the database were searched:

Treecd 1939 to 1972

Treecd January 1973 to July 1997

Agricola January 1984 to December 1991

CAB (Commonwealth Agricultural Bureau) abstracts 1984 to 1986

CAB abstracts 1987 to 1989

CAB abstracts 1990 to 1991

CAB abstracts 1992

CAB abstracts 1993 to 1994

CAB abstracts 1995

CAB abstracts January 1996 to April 1997

Classification of the Literature

To examine the extent of socioeconomic research conducted under each of the nine biological S&T networks of the CFS, we classified the literature into nine categories by assigning each item to a single network according to the main issues addressed in the document. This process was awkward, because each paper cannot be distinctly viewed as dealing with issues that are relevant to only one network. Therefore, some papers address issues covered by networks other than the category in which they appear.

Moreover, our search revealed that very little socioeconomic research relevant to Forest Health and Forest Ecosystem Processes networks has been conducted. Consequently, the first section covers literature on three networks: Pest Management, Forest Health, and Forest Ecosystem Processes.

Pest Management, Forest Health, and Forest Ecosystem Processes

Amacher, G.S.; Brazee, R.J.; Thomson, T.A. 1991. The effect of forest productivity taxes on timber stand investment and rotation length. For. Sci. 37(4):1099-1118.

At the outset, the authors emphasize the importance of understanding the impacts of different taxation regimes on sustainable forest management in the USA. They modeled the qualitative and quantitative effects of productivity taxes and concluded that the effects of such taxes on rotation length and initial stand investment cannot be predicted a priori for a number of reasons, including complementarity or noncomplementarity of rotation length and initial stand investment in the stumpage volume function and dependence of rotation length and initial stand investment on, among other factors, the volume function, the tax rate, the interest rate, and the amount of the imposed productivity tax.

Anderson, W.C.; Guldin, R.W.; Vasievich, J.M. 1987. Assessing the risk of insect attack in plantation investments: foresters can use Monte Carlo simulation to quantify the chances of a reasonable return. J. For. 85(1):46-47.

The risk of attack by destructive insects complicates forest management decision making. Where insects pose an uncertain threat, traditional investment analysis methods, such as cost-benefit analysis, are inadequate for guiding efficient allocation of scarce resources among alternative options. The authors used the Hertz-Thomas simulation method of risk analysis to determine if landowners could obtain reasonable return on investments in loblolly pine plantations in the Southern Coastal Plain of the USA. Silvicultural treatments, mainly different levels of thinning, were applied on the experimental plantations. The authors concluded that there was higher attack level in unthinned stands than in thinned stands. Moreover, unthinned stands accrued significantly lower rates of return on investments than thinned stands.

Bakke, A. 1991. Socioeconomic aspects of an integrated-pest-management program in Norway. For. Ecol. Manage. 39:299-303.

To counter severe outbreaks of bark beetle in southern Norway, the government introduced an extensive integrated pest management program in 1979. In this relatively short article, the author discusses the various aspects of that program. The scientific, technological, economic, administrative, and information challenges to effectively manage that particular project are described succinctly.

Basham, J.T. 1984. Degradation and loss of wood fibre in spruce budworm-killed timber, and effects on utilization. For. Chron. 60(1):10-14.

The author's objective is to provide information on salvaging timber damaged by spruce budworm. After a brief review of the literature on the impacts of defoliation caused by spruce budworm, he suggests when and how damaged timber should be harvested, stored, and used.

Baughman, M.J. 1985. Economics of Dutch elm disease control: a model and case study. J. For. 83(9):554-557.

To assess the economic efficiency of sanitation controls for Dutch elm disease, the author conducted a case experiment in Minneapolis, Minn., on alternative techniques: intensive sanitation, winter sanitation, and minimum control techniques. The costs and benefits for each technique were predicted. It was concluded that intensive sanitation generates the highest return on investment, as indicated by net present worth. In other words, intensive sanitation technique saved the most trees at the lowest cost.

Buse, L.J.; Wagner, R.G.; Perrin, B. 1995. Public attitudes towards forest herbicide use and the implications for public involvement. For. Chron. 71(5):596-600.

Because of environmental concerns, public opposition to herbicide use in forest vegetation management is an important issue for forest managers. The authors examine public concerns and develop approaches that might enable forest managers to gain public support. They conducted a study consisting of a comprehensive literature review, discussions with 12 focus groups, and a review of current strategy for public involvement. The authors suggest a procedure for public involvement in forest vegetation management. It includes information sharing, resource sharing, cooperative planning, and collaborative actions.

Carlson, G.A. 1979. Economics of forest pest management. U.S. Dep. Agric., For. Serv., Gen. Tech. Rep. WO-14:51-56.

The author provides a comparative-historical assessment of integrated pest management in agriculture and forestry, in terms of trends in costs per hectare. He describes precautionary or insurance application of pesticides in forestry as one of the most serious resource allocation problems. Alternative strategies are suggested, specifically careful application of pesticides, early harvest of threatened timber crop, and letting pest infestation occur and allowing decline in tree growth until marginal gain equals marginal cost (where gain and cost are applied to the postattack forest stand).

Deloite and Touche Management Consultants. 1992. An assessment of the economic benefits of pest control in forestry. For. Can., For. Pest Manage. Inst., Sault Ste. Marie, ON. 156 p. + appendixes.

This comprehensive report starts with a discussion of the national importance of Canada's forests, in quantitative terms (e.g., employment, outputs, shipments, and amenity values). This section is followed by descriptive and quantitative analyses of the impacts of pests on forest stands. The study concludes that the forest sector's multiple benefits are essential to Canadians; that there is a need for sustainable management of forests to satisfy the diverse needs that society places on them; that there is an increasing trend in demand for timber, such that demand exceeds supply; that the impacts of uncontrolled pests on forest productivity and health are significant; that the economic return on pest control expenditures is high; and that the benefits of pest control are especially high in forest-dependent communities.

Deloite and Touche Management Consultants. 1992. Economic benefit assessment of triclopyr in forest management. For. Can., For. Pest Manage. Inst., Sault Ste. Marie, ON. 102 p. + appendixes.

An economic benefit assessment of triclopyr, which is used for controlling competing forest vegetation, was conducted. The study focused on one case in New Brunswick. Five vegetation control options were examined for the potential impact on timber supply: triclopyr applied to all forest stands; triclopyr applied to shade-tolerant stands only (3 of 7 stands) and glyphosate applied to remaining 4 stands, glyphosate applied to all forest stands, manual methods applied to all forest stands, and no vegetation control methods, with offsetting higher annual plantings. The study concludes that aerial application of herbicides for vegetation control in forestry results in positive financial returns and other economic spin-offs in terms of jobs and value added. The use of triclopyr would generate the largest net benefits relative to glyphosate for that forest license and others with a similar vegetation complex. Sole reliance on manual methods of vegetation control would result in substantial financial losses.

Gansner, D.A.; Herrick, O.W. 1984. Guides for estimating forest stand losses to gypsy moth. North. J. Appl. For. 1(2):21-23.

The objective of the paper is to provide guides for cost-effective management of gypsy moth. To test their techniques, the authors analyzed primary data collected from experimental plots during outbreaks in Pennsylvania. Their technique, which appears to be straight-forward, is expected to be used for predicting forest stand losses to the pest.

Herrick, O.W. 1981. Forest pest management economics–application to the gypsy moth. For. Sci., 27(1):128-138.

This paper looks at the best level of investment that is required to control gypsy moth by examining the incremental value of timber protected versus its cost. The least-cost-plus-loss economic theory is used to show that with incremental analysis of impacts and costs, maximum efficiency in forest pest management can be achieved. The author concludes that to achieve efficient pest management, the size and intensity of the infestation, the physical and economic impacts, and the costs of control must be considered jointly.

Herrick, O.W.; Gansner, D.A.; DeBald, P.S. 1979. Predicting stand losses from the gypsy moth: an application of automatic interaction detection. J. For. 77(2):91-94.

The authors developed techniques for predicting the amount of tree mortality and the value timber loss that could result from gypsy moth infestation. Of 59 forest stand characteristics (variables) examined, crown condition, elevation, tree-size distribution, species, and position on slope were the best predictors of risk of tree mortality from defoliation by the pest.

Hollenhorst, S.J.; Brock, S.M.; Freimund, W.A.; Twery, M.J. 1993. Predicting the effects of gypsy moth on near-view aesthetic preferences and recreation appeal. For. Sci. 39(1):28-40.

The goal of the study was to provide resource policymakers, public land managers, tourism developers, and private landowners with useful information for making decisions regarding effective management of gypsy moth. The authors used the scenic beauty estimation approach. Near-view color photographs were taken of 25 forested Central Appalachian Plateau sites that exhibited tree mortality induced by gypsy moth. The slides were randomly arranged and presented to 400 subjects who rated them on a 10-point preference scale. The authors concluded that from the standpoint of near-view aesthetics or recreation value, expenditures for controlling gypsy moth might be necessary only in stands where tree mortality is expected to be unusually severe.

Holmes, T.P. 1991. Price and welfare effects of catastrophic forest damage from southern pine beetle epidemics. For. Sci. 37(2):500-516.

Epidemics of southern pine beetle have been responsible for periodically catastrophic levels of mortality to southern yellow pine forests in the USA. The author argues that traditional techniques for appraising forest damage, developed for site-specific economic analysis, are theoretically unsound, because they do not take into account aggregate impacts across ecosystems and related marketplaces. To remedy the limitations of "traditional approaches," the author developed an economic model of timber supply and demand. He used it to construct "a new technique" for estimating short-run market-level impacts of catastrophic forest damages. A null hypotheses that catastrophic disruption of forest ecosystem production has no effect on timber markets was tested using intervention analysis with data on the Texas-Louisiana epidemic. Parameter estimates were used to compute short-run changes in economic welfare for producers in damaged forests, producers in undamaged forests, and timber consumers. The author

concluded that changes in social welfare resulting from cata-strophic damage to standing timber across forest ecosystems require market-level analysis and that the net change in economic welfare resulting from insect epidemics is unambiguously negative.

Huang, Y.S.; Teeter, L. 1990. An economic evaluation of research on herbaceous weed control in southern pine plantations. For. Sci. 36(2):313-329.

As financial resources for research increasingly become scarce, mainly because of cutbacks in public funds, forestry and other research institutions are attempting to meet their mandates by setting priorities (i.e., by selectively canceling research projects). This situation has led to the need to establish an evaluation framework for forestry research. In this paper, the authors describe an ex ante model, which uses forecasts of the future benefits of current and proposed research. They used this model to evaluate a research program that focused on enhancing pine growth by controlling competition from herbaceous weeds. The method required information fully describing the impact of weeds on pine growth, the probability of future research success, the probability and rates of adoption of future technology, the management strategies of potential users of the technology (weighted by the area and quality of lands under their control), the costs of research extension and technology adoption, and the future stumpage value. The authors conclude that past and planned herbaceous weed control research would produce substantial net economic benefits if techniques developed by researchers were applied to the management of pine forest types in the southern USA.

Irland, L.C. 1979. Not any green thing ... notes on the economics of forest pest management. U.S. Dep. Agric., For. Serv., Gen. Tech. Rep. WO-14:43-50.

The article is a general commentary on issues relevant to the economics of forest pest management, including vegetation management. The author provides a review of the economics of forest pest management, including the importance of resource values in decisions in this area, the impact of integrated pest management on costs, and cost-sharing issues. The impacts of spruce budworm infestation and control, specifically individual stand effects, regional effects on timber harvests, valuation of losses, and the social costs associated with pesticide use, are used to review resource values. The author concludes that future work on integrated pest management should include improvements in survey and detection systems, the development of effective cultural measures to reduce the vulnerability of forest stands before outbreaks occur, improvements in insecticides and application methods, improvements in impact and economic analysis techniques, and more sophisticated pest management, as well as well-planned demonstration projects.

Jokela, E.J.; Harding, R.B.; Nowak, C.A. 1989. Long-term effects of fertilization on stem form, growth relations, and yield estimates of slash pine. For. Sci. 35(3):832-842.

A 25-year-old slash pine plantation in northern Florida was used to evaluate the long-term effects of time-of-planting phosphorus fertilization on stem form. For different treat-ments, cylindrical form factor, relative taper curves, the constant-stress principle of stem formation, tree volume, and equations for estimating biomass were compared. The results revealed that it is unnecessary to develop treatment-specific equations for quantifying fertilizer responses for slash pine on phosphorus-deficient sites.

Klemperer, W.D. 1983. Ambiguities and pitfalls in forest productivity taxation. J. For. 81(1):16-19.

The author argues that a productivity tax might be more discouraging to the purchase of bare land than an unmodified ad valorem tax. When the present value for a given area is considered, the burden on land-purchase and reforestation decisions tends to be increased because productivity taxes are distributed

more toward the beginning of the rotation than is the ad valorem tax. Inappropriate methods for selecting the capitalization rate can cause productivity valuations to vary with the inflation rate, which also adds to the burden of land purchase.

Liebhold, A.M.; Berck, P.; Williams, N.A.; Wood, D.L. 1986. Estimating and valuing western pine beetle impacts. For. Sci. 32(2):325-338.

The authors developed a model of tree growth and mortality to simulate timber production with and without tree mortality caused by the western pine beetle. They discounted stumpage value at the time of harvest back to the time of mortality and used estimates of logging costs as proxy for revenues generated from salvaging killed trees. These values were used to estimate the value of tree mortality caused by western pine beetle. The authors concluded that the credibility of their estimates of the beetle's impact was affected by interest rate, time of final harvest, spatial aggregation of mortality, and distribution of tree mortality in relation to tree diameter and stand density. Consequently, it was difficult for them to draw a credible conclusion on the economic and financial impacts of the pest.

McKetta, C.; Blatner, K.A.; Graham, R.T.; Erickson, J.R.; Hamilton, S.S. 1994. Human dimensions of forest health choices. J. Sustain. For. 2(1 & 2):135-149.

The authors assert that the health of forest resources in the Inland West of the USA has been influenced by over a century of socio-economic activities. They discuss the use, contributions, and limitations of neoclassical microeconomic theory in understanding the implications for forest health of various management options. The three strategic objectives of forest management – ecosystem management, commodity production, and protection – are described in the context of socially and economically optimal forest health activities. The paper does not provide demonstrative quantitative analysis techniques.

Mercier, J.C. 1985. Protection of the forest: a social and economic imperative. For. Chron. 61(4):378-381.

In this short article (a speech given at an international conference), the author, a federal deputy minister, describes the socioeconomic importance of the forest sector in Quebec, with direct and indirect employment of 250 000, a payroll of $1.2 billion, and annual export earnings of $3 billion. He emphasizes the need for increased protection measures for the forest against diseases, insects, and wildfire.

Nair, K.S.S. 1991. Social, economic and policy aspects of integrated pest management of forest defoliators in India. For. Ecol. Manage. 39:283-288.

This paper provides useful information on the social, economic, and public policy hindrances to the development of an effective and efficient integrated pest management strategy in India. The author believes, however, that with the establishment of a new scientific organization, the Indian Council of Forestry Research and Education, the problem will be at least alleviated. Emphasizing the importance of integrated pest management, he contends that it was only neglect of forest pest control in India that saved the forest ecosystem from the "onslaught of chemical pesticides."

Ondro, W.J.; Constantino, L.F. 1990. Financial returns from fertilizing 70-year-old lodgepole pine near Hinton, Alberta. For. Chron. 66(3):287-292.

Fertilization experiments were conducted on fully stocked, 70-year-old lodgepole pine stands on sites of medium to high productivity in the Lower Foothills Section of the Boreal Forest Region of Alberta. Two soil types were tested: Coalspur (Orthic Gray Luvisol, with some Podzolic Gray Luvisol) on western and northern aspects and Mercoal (Podzolic Gray Luvisol) on southeast aspects. Net present worth and internal rate of return, respectively, were the criteria used for ranking and for profitability tests of the treatments. The authors

conclude that fertilization of lodgepole pine under the described conditions was financially viable.

Reed, W.J.; Errico, D. 1987. Techniques for assessing the effects of pest hazards on long-run timber supply. Can. J. For. Res. 17(11):1455-1465.

Acknowledging at the outset the difficulty of modeling the effect of pest infestation on forest output, the authors developed stand-level and forest-level models for assessing the effects of pest hazards on long-term timber supply. The stand-level model provides formulas for the estimation of long-run average yield and the land expectation value, when the risk of both infestation by pests and fire exist. Moreover, their forest-level model, a harvest scheduling procedure, allows for pest infestation and fire damage. They demonstrate applications of their models using data on mountain pine beetle in the Quesnel Timber Supply Area of British Columbia.

Rose, D.W. 1983. Benefit-cost evaluation of the Douglas-fir tussock moth research and development program. J. For. 81(4):228-231.

The author used a basic cost-benefit analysis to evaluate an expanded research and development program for Douglas-fir. He also conducted sensitivity analysis under different assumptions. Although he supports increases in research funding, he cautions that there is a need for careful analyses before final decisions on funding are made.

Tobi, D.R.; Grehan, J.R.; Parker, B.L. 1993. Review of the ecological and economic significance of forest Hepialidae (Insecta: Lepidoptera). For. Ecol. Manage. 56:1-12.

The authors describe Hepialidae as primitive moths that damage trees when larval tunneling and feeding cause wood defects. Hepialidae that feed on leaf litter, ground herbs, or grasses do not cause problems for trees; it is the species that feed on roots or bore into tree trunks and branches that have economic and environmental importance in forestry. This article looks at the short-term and long-term consequences of Hepialidae on forest growth and management. The authors conclude that Hepialidae have generally low economic and ecological impacts.

Williams, J.R. 1985. A private landowner perspective of state policy, economics and responsibility in spruce budworm control. For. Chron. 61(4):388-393.

The author starts highlighting the conflicting interests of a private landowner and the pest control policy of the State of Maine. In that state, International Paper owned 800 000 acres (323 748.80 ha) of timberland, stocked with spruce and fir that experienced damage from spruce budworm. In 1982, in collaboration with International Paper, the state conducted an aerial spray program. However, following changes in state policy and administration, program costs, landowner objectives and responsibilities, and marketing requirements, the company withdrew from the program in 1983 to do its own protection work. Taking into account this scenario, the author conducted a cost-benefit analysis. He makes a general recommendation that the state leave the spray program to the private sector and concentrate its efforts on resource analysis, insect survey and detection, and research.

Plant Biotechnology

Cornelius, J.P.; Morgenstern, E.K. 1986. An economic analysis of black spruce breeding in New Brunswick. Can. J. For. Res. 16(3):476-483.

The authors evaluated the financial viability of a black spruce breeding program in New Brunswick. They concluded that variations in discount rates did not significantly influence the break-even level of discounted revenues; that at 4.4% internal rate of return, black spruce breeding is believed to lead to sustainable timber supply; and that the current strategies were near optimum.

Fins, L.; Moore, J.A. 1984. Economic analysis of a tree improvement program for western larch. J. For. 82(11):675-678.

The authors conducted a financial analysis for stands of genetically improved and unimproved western larch in northern Idaho. They used an individual-tree simulation model and an economic (financial) subroutine to determine optimum rotation ages, which, according to the authors, were the ages when the net present value would be maximized. They concluded that the tree improvement investment was financially viable at both 4% and 5% discount rates on excellent sites and at 4% on relatively good sites.

Gaston, C.; Globerman, S.; Vertinsky, I. 1995. Biotechnology in forestry: technological and economic perspectives. Technol. Forecasting Soc. Change 50:79-92.

With the objective of assessing the state of the art and future prospects of biotechnology application in forestry, the authors examine the impacts of derived demand for research and development, the nature of research and development suppliers and their motives, and the regulatory system on rates of innovation of biotechnology in forestry. They also identify an area of "market failure" caused by policy-related uncertainty, tenuous land ownership structure, long intergenerational horizons, and the public nature of the goods and services produced by the forest. To alleviate problems related to "market failure," the authors recommend improving tenure and stumpage systems to improve the certainty of property rights; providing compensation for public-goods production; and increasing the level of funding for research and development. Furthermore, the authors argue that biotechnology in forestry applications holds very good promise in the long run: it offers the possibility of improved forest conservation as well as increased quantity and quality of timber harvested, which would allow for the customization of fiber production. The notion is that customization of fiber production might result in downstream product differentiation and cost reduction.

Hasnain, S.; Pigeon, R.; Overend, R.P. 1986. Economic analysis of the use of tissue culture for rapid forest improvement. For. Chron. 62(4):240-245.

The authors argue that the ability to produce sufficient gain in genetic material in a breeding program, through controlled crosses, and the utilization of the genetic gain (i.e., increased growth rate) are the two main conditions determining the economic feasibility of using of tissue culture in forestry to reduce the length of rotation age. From their experimental results, they conclude that the cost of tissue culture plantlets would be relatively high but would be more than compensated by the savings realized because of reduced growth period (rotation age).

Ledig, F.T.; Porterfield, R.L. 1982. Tree improvement in western conifers: economic aspects. J. For. 80(10):653-657.

Applying a break-even cost-benefit analysis, the authors evaluated the financial viability of the National Forest System's tree improvement program for ponderosa pine in the Pacific Southwest and the "progressive tree improvement program" for Douglas-fir in the Pacific Northwest of the USA. They conclude that both tree improvement programs appeared to be capable of at least an 8% real rate of return on investment, if short rotations are used or if tree improvement is accompanied by thinnings. They further elaborate that the break-even cost-benefit analysis indicated that interest rate, real price, and increases in stumpage price were the major determinants of profitability.

Löfgren, K. 1988. On the economic value of genetic progress in forestry. For. Sci. 34(3):708-723.

The author describes a theoretical method for analyzing the financial and economic benefits of tree improvement. He introduces a number of general theorems on the properties of the present-value function of bio-technological parameters. Specifically, the author shows how the economic gains of tree improvement research ventures can be given

upper and lower bounds, which, to a certain extent, can be expressed in entities known from current management practices. Finally, he presents empirical results to prove the practical applicability of his theoretical model.

McKenney, D.W.; Davis, J.S.; Turnbull, J.W.; Searle, S.D. 1993. Impact of Australian tree species selection research in China: an economic perspective. For. Ecol. Manage. 60:59-76.

The authors report that the Australian Centre for International Agricultural Research, through collaborative research projects with the Commonwealth Scientific and Industrial Research Organisation, Australia, and the Chinese Academy of Forestry, has been involved in selection trials for tree species in southern China since 1984. The paper presents an assessment of the likely economic impact of the trials. The analysis is based on an ex ante approach, because of the long-term nature of forestry production. The authors conclude that the trial program could generate internal rates of return ranging from 27% to 45% and a present value of $72 million in 1986 Australian dollars.

McKenney, D.; Fox, G.; van Vuuren, W. 1992. An economic comparison of black spruce and jack pine tree improvement. For. Ecol. Manage. 50:85-101.

Applying a cost-benefit analysis, the authors evaluated black spruce and jack pine seed orchard programs in Ontario. The important factors that influence the programs were found to be stumpage values, the potential size (area) of the improved planting program, the magnitude of the genetic gain, the quality of the land base, the discount rate, and the fecundity of seed orchards over time. The authors conclude that jack pine tree improvement consistently outperformed black spruce tree improvement in terms of its economic potential.

Reed, F.L.C. 1989. The potential economic impact of biotechnology and related research on the forest sector. For. Chron. 65(3):185-189.

"The Canadian forest sector is at a critical juncture in maintaining its competitive position internationally," states the author in this qualitative but important analysis of research and development in the Canadian Forest Service. One reason that he identifies is the difficulty Canada is experiencing in holding the line on the costs of timber and its processing. He estimates the expenditure on silviculture alone to be from 10% to 20% of the cost of delivering roundwood to manufacturing plants and argues that the entire forest community is counting on forestry science, especially biotechnology, to enhance industry viability and provide solutions to problems associated with environmental quality. However, he contends, the funding of research and development in forestry has been handicapped by our inability to argue persuasively for science budgets. Then, he goes on to explain various approaches to the cost-benefit analysis of forestry research projects.

Talbert, J.T.; Weir, R.J.; Arnold, R.D. 1985. Costs and benefits of a mature first-generation loblolly pine tree improvement program. J. For. 83(3):162-166.

The authors analyzed the financial and economic viability of seed orchards for loblolly pine in the North Carolina State University–Industry Cooperative Tree Improvement Program. They found that investments in tree improvement efforts for loblolly pine were attractive. They conclude that despite the high production cost at the initial stage, tree improvement investments are financially viable, if careful planning measures are taken.

Westgate, R.A. 1986. The economics of containerized forest tree seedling research in the United States. Can. J. For. Res. 16(5):1007-1012.

At the outset, the author argues that there is extensive evidence for the significant positive effects of research and development on

productivity, which in turn result in economic growth and development. He defines a reforestation strategy that uses containerized forest tree seedlings as a forestry innovation. The author believes that the economic benefits resulting from the development of this method of reforestation are attributable to numerous sources, although he only considers the benefits measurable in terms of savings to consumers. He used an economic surplus model to estimate research benefits and found that the average internal rate of return on investment for research on containerized seedlings ranged from 37% to 111%, depending on assumptions concerning the percentage price differential between containerized bare-root seedlings, as well as research cost estimates. Finally, the author remarks on the usefulness of results from research evaluations, stating, for example, that research evaluation can provide background information for decision making, validate existing research projects, and verify or refute ideas.

Landscape Management

Alavalapati, J.; White, B.; Jagger, P.; Wellstead, A. 1996. Effects of land use restrictions on the economy of Alberta: a computable general equilibrium analysis. Can. J. Reg. Sci. 19(3):349-365.

By dividing the Alberta economy into five sectors—agriculture, forestry, energy, manufacturing, and services—the authors developed a computable general equilibrium model. The first three sectors, which depend on the natural resource base, were treated as net exporters, because the domestic demand for their outputs is considered less significant than their exports. The manufacturing sector was assumed to be a net importer, because domestic demand for manufactured goods exceeds domestic supply. The service sector included all services. The authors examined the impact of a set of hypothetical policies that would cause a 1% decrease in the use of land by the first three resource-based sectors. They conclude that under a wage-rigid assumption, regional income would decline and unemployment would rise in response to policies that restrict land use.

Baumgartner, D.C.; Hyldahl, C.A. 1992. Price risk analysis for private nonindustrial forest management. North. J. Appl. For. 9(2):55-57.

Using portfolio analysis, the authors show how to calculate the price risk of investments in managing individual forests and stands. They assert that, by observing annual price variability for various timber species and products, a forest manager can shift the timber growing-stock species mix toward a desired combination of risk and return.

Beck, J.; Constantino, L.; Phillips, W.; Messmer, M. 1989. Supply, demand and policy issues for use of aspen. For. Chron. 65(1):31-35.

By reviewing the demand for aspen by the panel and pulp mills and by considering supply factors such as stumpage availability, the authors examine the extent of derived demand for aspen roundwood in Alberta. They also assess the impacts of current policy changes on future utilization of aspen. They observe that at the time of the study aspen utilization in Alberta was increasing rapidly, with three OSB (Oriented Strand Board) mills and two pulp and paper mills using 800 000 m^3 and 1.5 million m^3 per year, respectively.

Beckley, T.M.; Korber, D. 1995. Sociology's potential to improve forest management and inform forest policy. For. Chron. 71(6):712-719.

By explaining why sociology has not played a significant role in forest management traditionally, the authors show the future need for sociological inputs into forest management decisions and the development of forest policy. They identify some key areas where sociology makes significant contributions, including community development and sustainability, holistic management of forest ecosystems (including societal issues), stakeholders' values, social movements that express the concerns of various social groups and communities, conflict

and conflict resolution, and natural resources and persistent rural poverty.

Belli, K.L.; Nautiyal, J.C. 1989. Production functions: a useful tool for forest management. For. Ecol. Manage. 29:267-275.

Using production-function specifications, the authors examined the biomass yield of a hybrid poplar in Canada and the growth of *Eucalyptus grandis* in Brazil. They conclude that production-function specifications are useful for determining elasticities of inputs and outputs, in the Canadian case, and for predicting yield under various planting conditions and assessing the economic feasibility of alternative treatment regimens.

Carson, D.M. 1995. Timber supply analysis: an industrial model from British Columbia. For. Chron. 71(6):735-738.

The author describes a model developed by Timberline Forest Inventory Consultants of British Columbia. The model "explicitly" deals with resource-demand objectives and measures, such as objectives for visual quality, measures for habitat protection, and guidelines for protecting water quality. It uses a "pseudo-geographic inventory" to simulate the intent of constraints on harvesting forest cover.

Clements, S.E.; Jamnick, M.S. 1990. Some considerations in modeling private woodlot timber supply. For. Chron. 66(1):41-44.

Arguing that private woodlot owners have diverse backgrounds, ownership arrangements (property rights), and management objectives, the authors identify—by reviewing the literature—variables and techniques for determining timber supply from private woodlots.

de Naurois, M.; Buongiorno, J. 1986. Economics of red pine plantation management in Wisconsin. North. J. Appl. For. 3(3):118-123.

Under given market prices and costs and using simulation experiments, the authors estimated the economic viability of a red pine plantation in Wisconsin. Their criteria were the values of soil expectation and the rate of return that would be obtained under different management alternatives. They conclude that it would be more economical to manage red pine plantations in Wisconsin for pulpwood and sawlog combined, rather than for pulpwood only, even on low-quality sites. They found that site quality was the most significant factor influencing the economic viability of plantations.

Dwyer, J.P.; Dey, D.C.; Kurtz, W.B. 1993. Profitability of precommercially thinning oak stump sprouts. North. J. Appl. For. 10(4):179-183.

To estimate the financial viability of pre-commercial thinning of oak stump sprouts (coppices), the authors estimated the incremental gains in yield and the net present value for five crop-tree release treatments of 5-year-old coppice sprouts in southeastern Missouri. They conclude that, given the growth response and timber price within the Ozark Region, precommercial thinning of oak stump sprouts is not financially and economically viable.

Forboseh, P.F.; Brazee, R.J.; Pickens, J.B. 1996. A strategy for multiproduct stand management with uncertain future prices. For. Sci. 42(1):58-66.

The authors explain a theoretical model for stand management with multiple series of stochastic prices. They argue that, when the only decision is to reject or accept a set of prices

for a clear cut, the strategy should be to accept and clear cut in the current period, if the revealed revenue is at least as large as the current reservation revenue. This strategy was found to be optimal when the price process is stationary and temporarily independent, with the possibility of cross-product price dependence. The authors conducted a simulation involving red pine yields, classified into two products, pulp and sawtimber, and found that the reservation-revenue harvest strategy was far more consistent with current management practice than that found by previous analyses involving a single product, sawtimber.

Freeman, A.M., III; Portney, P.R. 1989. Economics clarifies choices. J. For. 87(11):34-38.

In this short but important descriptive analysis, the authors present several points on the role of socioeconomic analysis in environmental quality control. Difficult choices must be made, they argue, about how best to control particular environmental risks with the limited budgetary resources available. In conclusion, they make the point that these types of choices invariably involve trade-offs, and economics helps with these decisions by providing information on the pros and cons of particular courses of action.

Grossman, G.H.; Potter-Witter, K. 1991. Economics of red pine management for utility pole timber. North. J. Appl. For. 8(1):22-25.

Arguing the justifications for considering timber for utility poles separately, rather than including it in sawtimber, the authors conclude that including utility poles in red pine management regimes leads to distinctly different management recommendations, and where a market for utility poles exists, managing for poles will maximize net returns. For example, at a 4% discount rate, land-owners in Michigan's Lower Peninsula can increase the soil expectation value of their investment from US$4 per acre to US$104 per acre (US$9.88 per hectare to US$256.88 per hectare) by managing for poles along with pulpwood and sawtimber on a site index of 75 ft of well-stocked stands.

Haight, R.G. 1985. A comparison of dynamic and static economic models of uneven-aged stand management. For. Sci. 31(4):957-974.

The author used numerical techniques to compute the discrete-time sequence of residual dimensions that maximize the present net worth of harvestable volume from uneven-aged stands. His results contradicted the optimal steady-state diameter distributions determined with static analysis. In this paper, he establishes optimality conditions for solutions to dynamic and static harvesting problems. The author concludes that for a stand with any diameter distribution, the optimal transition regime does not converge to the steady state that maximizes land expectation value according to the Faustman equation, the present net worth of the optimal transition and steady-state regime is greater than the present net worth of the statically determined steady-state regime, and the optimal steady-state regime is invariant.

Harms, J.C.; Johnson, J.E.; Johnson, P.W.; Stier, J.C.; Guries, R.P. 1990. Market assessment and economic potential of the red pine utility pole industry in Wisconsin. North. J. Appl. For. 7(4):189-193.

By summarizing statistical facts, the authors discuss the economic importance of the red pine utility pole industry in Minnesota, Iowa, Illinois, Michigan, and Wisconsin. The industry's structure, the key market forces that influence performance of the industry, and some forest management strategies related to the increasing demand for utility poles are discussed.

Harris, C.C.; Driver, B.L. 1987. Recreation users fees I. Pros and cons. J. For. 85(5):25-35.

The importance of and the techniques for collecting cost recovery revenue from recreation user fees are discussed. Also summarized in this article are the findings and recommendations of the President's Commission on American Outdoors, which was established in 1985 to review existing outdoor recreation policies, programs, and

opportunities and to recommend actions to meet future recreation needs.

Hof, J.G.; Field, R.C. 1987. On the possibility of using joint cost allocation in forest management decision making. For. Sci. 33(4):1035-1046.

The authors developed what they called a refutable-theoretical hypothesis to examine joint cost allocation schemes. They tested their hypothesis in a test case involving a managed forest in Alabama. They tested seven allocation schemes: separable cost-remaining benefits, nucleolus, proportional nucleolus, weak nucleolus, benefit-included nucleolus, Shapley value, and generalized Shapley value. The authors conclude that joint allocation schemes are not likely to lead to correct output-level decisions.

Hyberg, B.T. 1987. Multiattribute decision theory and forest management: a discussion and application. For. Sci. 33(4):835-845.

The author describes a procedure required to implement multiattribute decision theory. He applies it to the management of a stand of timber owned by a nonindustrial private forest landowner who wanted to maximize both timber income and aesthetic benefits. He concludes that harvesting and regeneration procedures of intermediate intensity maximize the well-being of a segment of such landowners.

Lippke, B.; Oliver, C.D. 1993. Managing for multiple values: a proposal for the Pacific Northwest. J. For. 91(12):14-18.

The authors discuss two approaches that can be used for providing wildlife habitat and preserving biodiversity as well as other ecological values. The techniques, which were first advanced by others, are known as the natural reserves approach and the landscape management approach. The natural reserves approach focuses on preserving areas on public and private lands for protecting threatened species or specific habitat conditions, and the landscape management approach deals with the management of forest structures to provide a range of stand conditions and hence a broader balance of biodiversity and habitats.

Luckert, M.K.; Haley, D. 1989. Forest tenures—requirements, rights and responsibilities: an economic perspective. For. Chron. 65(3):180-182.

The paper discusses the nature of forest tenure arrangements in terms of requirements, rights, and responsibilities. The authors argue that the standard of private management of Crown lands frequently falls below public expectations, because the benefits that rights confer on tenure-holders are entirely, or partially, appropriated for the Crown through the imposition of stringent legal requirements or because the rights themselves are of ambiguous legal status and noncompensable, which introduces considerable uncertainty into forest tenure arrangements. They conclude that without a secured tenure system, tenure-holders have less incentive to voluntarily manage Crown forests.

Marshall, P.L. 1986. A decision context for timber supply modeling. For. Chron. 62(6):533-536.

Discussing the difficulties associated with projecting timber supply, the author describes an approach to forecasting timber supply within the context of the management of the forest as a whole. He describes management of the timber resource as a subproblem of managing the forest, showing that the timber management plan comprises the answers to two intricately linked questions: how much to harvest over time and how to schedule a sequence of activities to obtain the desired rate of harvest.

Michie, B.R.; McCandless, F.D. 1986. A matrix model of oak-hickory stand management and valuing forest land. For. Sci. 32 (3):759-768.

The authors developed a diameter-class matrix model of oak-hickory stands for analyzing the economics of naturally regenerated even-aged hardwood forests. The model is expected to address the inherent differences between the management of naturally regenerated forests and the management of traditional plantations. They compared the values of liquidating a stand in one harvest and in two harvests. The value of maintaining an oak-hickory stand in even-aged management forever was determined for existing stands by calculating the present value of two variable harvests plus an infinite series of identical rotation. The authors conclude that, in cases of vast acreage of oak-hickory stands, it might not be feasible to convert all or even a large part to an alternative use (e.g., housing development) in a short period of time. For individual tracts, however, the authors argue that it is relatively easy to customize management plans on the basis of current stand conditions and assumptions of price, interest rate, and harvest cost. The authors contend that this type of analysis is useful for comparing the expected returns from alternative land uses under both short- and long-run planning horizons.

Newman, D.H.; Wear, D.N. 1993. Production economics of private forestry: a comparison of industrial and nonindustrial forest owners. Am. J. Agric. Econ. 75(3):674-684.

Using a restricted profit function, the authors compare the production behavior of industrial and nonindustrial private forest landowners in the southeastern United States. They modeled profits as a function of two outputs, sawtimber and pulpwood, one variable input, regeneration effort, and two quasi-fixed inputs, land and growing stock. They rejected the idea that the two types of ownership have identical profit function, found behavior consistent with profit-maximization motives under both types of ownerships, and observed similar responses to changes in input and output prices.

Niese, J.N.; Strong, T.F. 1992. Economic and tree diversity trade-offs in managed northern hardwoods. Can. J. For. Res. 22(11):1807-1813.

*With the objective of examining profit*ability and the ability to enhance or maintain species diversity under alternative management options, the authors used Shanon's index to measure regeneration diversity for eight even- and uneven-aged cutting methods and to determine net present value. They conclude that there are clear differences in financial returns and regeneration diversity with various cutting methods. Medium-selection treatment produced the highest diversity index of all uneven-aged treatments and the highest economic returns. Quality sawlog production and compatibility with aesthetic objectives were observed to be additional benefits of that management option.

Niese, J.N.; Strong, T.F.; Erdmann, G.G. 1995. Forty years of alternative management practices in second-growth, pole-size northern hardwoods. II. Economic evaluation. Can. J. For. Res. 25(7):1180-1188.

The authors analyzed potential economic returns in relation to tree quality for four uneven-aged cutting treatments and a control in a Wisconsin northern hardwood stand. They used a marginal analysis approach to assess the economics of changes in tree quality, considering tree grade, lumber volume yields, reported market values of lumber, and hardwood management costs. They found that net present values were highest for the heavy individual-tree selection treatment. They also observed that residual tree quality improved significantly with this treatment. Furthermore, they explain that the light-selection treatment produced the highest residual stand value, but low harvest revenues. The medium selection treatment had the greatest improvement in tree quality as well as high economic returns.

Perez-Garcia, J.M. 1995. Global economic and land use consequences. J. For. 93(7):34-38.

In this short article, the author reviews economic and land-use consequences of short-term changes in timber supply, focusing on the Pacific Northwest in the USA and British Columbia in Canada. The main point he makes is that, at a global level, the effects of withdrawal of timberland would be trade-offs between foregone timber production and increased habitat preservation in one region and greater forestland use in other regions, where environmental protection might be less strict.

Reed, W.J. 1993. The decision to conserve or harvest old-growth forest. Ecol. Econ. 8(1):45-69.

By incorporating uncertainty in future amenity values for standing forest and in future revenues for harvested timber, the author formulates a stochastic decision problem in continuous time for decision to harvest or conserve old-growth forest. He shows how the decision problem can be expressed as an optimal stopping problem, which can be solved analytically. He concludes that the optimal decision rule depends on how the ratio of current timber value to current expected present value of amenity benefits foregone through harvesting compares with some critical level. He includes an important discussion on the effects of changes in uncertainty and other parameters on the optimal rule and on how the cost-benefit analysis and certainty equivalence procedures could lead to premature harvesting decisions.

Row, C.; Kaiser, H.F.; Sessions, J. 1981. Discount rate for long-term forest service investments. J. For. 79(6):367-369.

After reviewing the importance of selecting an appropriate discount rate in forestry investment decisions, the authors recommend that the United States Department of Agriculture Forest Service use a discount rate of 4% in evaluating long-term investments. They argue that the 4% discount rate approximates the long-term measures of the opportunity cost of capital in the private sector of the US economy.

Salkie, F.J.; Luckert, M.K.; Phillips, W.E. 1995. An economic analysis of landowner propensity for woodlot management and harvesting in northwestern Saskatchewan. For. Chron. 71(4):451-458.

Using primary (survey) data, the authors analyze responses of woodlot owners to emerging timber markets and discuss the mechanisms that could be used to overcome some of the factors that are believed to impede the development of a viable private-forest sector in Saskatchewan. They conclude that approximately half of those interviewed would consider timber management and harvesting in the future. A logit analysis indicated that the propensity of landowners to manage and harvest their woodlots depended on several characteristics, including the diversity of farm operations, the length of family tenure of the land, the number of ways in which respondents use their forestland, and the area of the woodlot owned.

Solberg, B.; Haight, R.G. 1991. Analysis of optimal economic management regimes for *Picea abies* stands using a stage-structured optimal-control model. Scand. J. For. Res. 6:559-572.

To determine optimal treatment regimes for Norway spruce plantations, the authors developed a stage-structure model for projecting growth and yield combined with a gradient-based algorithm. The growth model was used to forecast the movement of trees between 3-cm diameter classes, according to a growth matrix that included nonlinear equations for diameter growth. The model allowed determination of optimal thinning time, thinning intensity, and thinning type, while the optimization model was used for determining treatment regimes with and without thinning for a wide range of values for economic and biological parameters. The authors conclude that optimal planting density is highly sensitive to interest rate, logging costs, planting costs, and site class. For given economic parameters, the

optimal planting density is not sensitive to the number of thinnings carried out or to the thinning intensity.

Vehkamäki, S. 1996. Economic comparison of forest management methods. For. Ecol. Manage. 82:159-169.

By comparing the financial and economic efficiency of even-aged and uneven-aged forest management strategies, the author examined the decision-making behavior of Mexican forest managers. He derived a production function and a forest dynamics function. He found that the production function exhibited decreasing marginal returns for management effort. The dynamics of the volume of growing stock were linear functions of the lagged volume and management effort. The even-aged stand management method was economically more efficient than the uneven-aged stand management method.

Weber, L.J. 1991. The social responsibility of land ownership. J. For. 89(4):12-17.

In this short article, the author presents philosophical arguments on the use and management of land-based resources. He focuses on the ethics of profit making, the rights and freedoms of individual citizens to own and use land in a socially responsible way, and the cultural norms and values that should be considered at the community level.

Zinkhan, F.C. 1995. Forest economics: the management of options and values. J. For. 93(1):25-29.

Arguing that traditional economic approaches to valuing forest resource management alternatives ignore the importance of managerial flexibility, the author suggests the integration of option pricing. Forest economists should, he argues, recognize the value of managerial flexibility and contingent valuation methods applied to estimating nonmarket benefits as they develop forest-value approaches consistent with the profession's operating environment, evolution, and increased recognition of public rights.

Impacts of Forestry Practices

Adams, D.M.; Alig, R.J.; McCarl, B.A.; Callaway, J.M.; Winnett, S.M. 1996. An analysis of the impacts of public timber harvest policies on private forest management in the United States. For. Sci. 42(3):343-358.

The authors examine the effects of changes in public policy with respect to the level of timber harvest in the USA. They develop an intertemporal model of US log markets in which prices, private harvest, and private forest management investment are endogenized. The sensitivity of projections to key exogenous inputs is illustrated by shifting the discount rate, management costs, and intertemporal demand trends. Then, they simulate a selected set of alternative public policy scenarios for the timber harvest and examine the impacts on private harvest and management, as well as welfare shifts among groups and regions. Given a perfect market structure, the authors conclude that the results of their simulation showed a far more elastic market response to changes in the level of public timber harvest than has been found in previous studies.

Adams, D.M.; Haynes, R.W.; Dutrow, G.F.; Barber, R.L.; Vasievich, J.M. 1982. Private investment in forest management and the long-term supply of timber. Am. J. Agric. Econ. 64(2):232-241.

To determine the behavior of private forest owners in the USA regarding both harvest and forest management decisions, the authors developed a model for private timber supply. They compared two 50-year projections: one assuming constant forest management intensity and the other using a harvest-investment model. They found that projected levels of investment would have little impact on markets before the year 2000, would stabilize real wood prices after the year 2000, would eliminate softwood timber imports by 2030, and would

expand the dominant role of southern forest regions in the markets for wood products.

Alavalpati, J.R.R.; Percy, M.B.; Luckert, M.K. 1997. A computable general equilibrium analysis of a stumpage price increase policy in British Columbia. J. For. Econ. 3(2):143-169.

Using a computable general equilibrium model, the authors investigated the impact of an increase in stumpage fees on the British Columbia economy and on the income distribution of two income classes and two regions in the province. They conclude that the policy would cause a significant decline in employment and income. Furthermore, they argue that the decline in real gross domestic product would be more than the fall in real income, that the income of average households would fall by more than that of poor households in response to the policy shock, and that the negative economic effects of the increase in stumpage fees (i.e., the policy change) would be higher in the British Columbia Interior than on the coast.

Baker, B.; Roberts, D.G. 1990. The potential effects of phase two of tax reform on Canada's forest sector. For. Chron. 66(6):590-595.

In this descriptive (nonempirical) paper, the authors examine the effects of Bill C-62, a sales tax reform bill that was introduced by the federal government in 1990, on the economic performance of the forest sector. They conclude that the impact was "generally positive" and that benefits were foregone because of a lack of corresponding provincial sales tax reform.

Bare, B.B.; Opalach, D. 1988. Determining investment-efficient diameter distributions for uneven-aged northern hardwoods. For. Sci. 34(1):243-249.

Describing the limitations of the so-called de Liocourt distribution constant approach, the authors argue that "balanced" diameter distributions are not investment efficient and are not necessary to achieve sustentation of production over a fixed cutting cycle. Their findings are based on a northern hardwood mixed-species growth model and a Weibull distribution function.

Binkley, C.S.; Percy, M.; Thompson, W.A.; Vertinsky, I.B. 1994. A general equilibrium analysis of the economic impact of a reduction in harvest levels in British Columbia. For. Chron. 70(4):449-454.

Using a computable general equilibrium model, the authors examined the economic and social impacts of possible reductions in the annual allowable cut in British Columbia. They conclude that the negative socioeconomic impacts of reducing the annual allowable cut would be reflected in increased unemployment and community instability, which, they say, were higher in the model than expected.

Blinn, C.R.; Sinclair, S.A. 1986. Profitability of various timber harvesting systems as affected by product sorting and timber stand parameters. North. J. Appl. For. 3(4):167-172.

The authors used a computer simulation to examine the impact of various timber stand parameters on the profitability of five timber harvesting systems: forwarding (fell, limb, top, and buck with a chain saw), manual fell-chain saw buck, manual fell-mechanized slash, mechanical fell-mechanized slash, and whole-tree chip. They found that the forwarding system was more profitable than the others.

Brazee, R.; Mendelsohn, R. 1988. Timber harvesting with fluctuating prices. For. Sci. 34(2):359-372.

Arguing that traditional Faustman harvesting ignores random annual price fluctuations, the authors adapted an asset sale model. Then, they solved for the "optimal schedule" of reservations. They conclude that when the current price is above the reservation price, owners should cut that age class (otherwise they should wait another year) and that the flexible-price harvest policy

significantly increases the present value of expected returns over the more rigid Faustman model.

Brazee, R.; Mendelsohn, R. 1990. A dynamic model of timber markets. For. Sci. 36(2):255-264.

By developing a theoretical model of timber markets, the authors analyze the adjustment process that a competitive timber market should undergo as a result of unanticipated shifts in demand. They conclude that the adjustment process is characterized by an initial price shock, followed by a relatively long period of gradually changing prices, harvest ages, and harvest levels, and that this adjustment could lead to a new steady state characterized by a fully regulated forest managed with Faustman rotations.

Bullard, S.H.; Sherali, H.D.; Klemperer, W.D. 1985. Estimating optimal thinning and rotation for mixed-species timber stands using a random search algorithm. For. Sci. 31(2):303-315.

The authors formulated a nonlinear-integer programming model to examine the problem of optimal density over time for even-aged, mixed-species stands. They used number of trees cut by species and diameter class as decision variables. They estimated optimal thinning and final harvest age simultaneously, using heuristic random-search algorithms. They conclude that optimal solutions were estimated for problems with eight initial species-diameter class groups, projected for up to three discrete growth periods. However, they caution that such solutions merit further research for evaluating complex stand- and forest-level decisions.

Buongiorno, J.; Lu, H.C. 1989. Effects of costs, demand, and labor productivity on the prices of forest products in the United States, 1958-1984. For. Sci. 35(2):349-363.

With the objective of investigating the reasons (causes) for changes in the prices of forest products over time, the authors developed a mark-up model of price formation. The model was designed to link yearly changes in price to changes in variable costs and demand. Annual data on prices, variable costs, and inventory-output ratios, for the period 1958 to 1984, for solid wood and pulp and paper products of the USA were used. Depending on the type of industry, the model explained 83% to 98% of the variations in annual prices; rise and decline of variable costs had symmetric effects on prices, except for pulp mills.

Canham, H.O. 1985. Regional economic impacts of timber-based activities: a user's guide. North. J. Appl. For. 2(3):71-75.

This article describes an impact analysis system of models, known as the regional timber-based system, and presents its user's guide. Different measures of regional economic impact and the principal models that were available for estimating the multipliers and direct and indirect impacts are highlighted. The author further states that the timber-based system of a region contains four major blocks of activities, representing the physical flows of wood through the processing system: forest land ownership and management, timber harvesting, primary processing, and secondary manufacturing.

Carroll, M.R.; Milne, G.R. 1982. Evaluating forest industry developments in Alberta using socioeconomic impact analysis. For. Chron. 58(6):268-274.

This paper examines the economic impacts of future expansion of the forest industry in north- central Alberta. Three mill types and two sites were selected. Six development alternatives were evaluated with a socioeconomic impacts analysis model. Economic impacts, classified as either social benefits or costs, were estimated for both the construction and the operational phases of each development option. The authors argue that their model might be an improvement on the general method of examining development proposals for forest resources in Alberta and elsewhere.

Carter, D.R. 1992. Effects of supply and demand determinants on pulpwood stumpage quantity and price in Texas. For. Sci. 38(3):652-660.

This paper presents a dynamic model of the Texas pine pulpwood stumpage market. The author incorporates profit maximization on the demand side and utility maximization on the supply side to analyze short-run market behavior. To reduce the problem associated with collinearity, a ridge regression form of three-stage least squares was used to estimate the model. Then, multipliers were constructed to predict the short- and long-run equilibrium impacts of supply-and-demand determinants on pulpwood quantity and price. As the income elasticity was much larger than the own-price elasticity, the author concludes that it might be more appropriate to consider the household production framework rather than the traditional profit-maximization model in analyzing short-run behavior.

Caulfield, J.P. 1988. A stochastic efficiency approach for determining the economic rotation of a forest stand. For. Sci. 34(2):441-457.

To incorporate risk aversion in rotation decisions, the author uses a stochastic dominance analysis. He demonstrates its application and compares his results with alternative decision rules, these being the deterministic land expectation value, the mean-variance rule, and the mean-coefficient of variation rule. He concludes that his results are consistent with those of previous studies, in that the inclusion of risk identifies risk-efficient rotation that might be shorter than in the deterministic case.

Cawrse, D.C.; Betters, D.R.; Kent, B.M. 1984. A variational solution technique for determining optimal thinning and rotational schedules. For. Sci. 30(3):793-802.

The authors used an optimal control modeling approach to formulate a timber harvest scheduling problem for even-aged stands. The harvest problem involved simultaneously determining the optimal thinning and harvesting schedule. They used maximization of present net value as a criterion over an infinite series of rotations. Under various assumptions, the authors used a variational solution technique to develop an optimal solution to the problem and validated it by developing a problem scenario.

Countryman, D.W.; Miller, H.R. 1989. Investment analysis of upland oak stands with sugar maple understories: management for oak vs. conversion to sugar maple in Iowa and Missouri. North. J. Appl. For. 6(4):165-169.

Land and timber expectation value, a modification of the Faustman formula, was used in this study. The authors argue that this method establishes a value (i.e., a price one can pay) for a parcel of land. They used their model to analyze the effectiveness of management scenarios typical of Iowa and Missouri for oak shelter wood, oak clear-cutting, oak underplanting, and conversion to sugar maple.

Dennis, D.F. 1989. An economic analysis of harvest behavior: integrating forest and ownership characteristics. For. Sci. 35(4):1088-1104.

To determine the factors that influence timber supply from private forests, the author developed a microeconomic model that encompasses the multiple objectives of private owners. He used a tobit analysis to estimate the relationship between harvest behavior and forest, owner, and economic characteristics from cross-sectional data for individual forest plots in New Hampshire. He concludes that forest characteristics and landowner affluence have significant impacts on decision to harvest.

Dwyer, J.F.; Schroeder, H.W. 1994. The human dimensions of urban forestry. J. For. 92(10):12-15.

In this nonempirical essay, the author discusses the concept of urban forestry and concludes that effective urban forest management programs rely on the support of urbanites. However, he argues further, that

support is most likely to develop when urbanites understand how trees and forests contribute to the quality of urban life, as well as what management strategy is needed to enhance that contribution. He suggests that the key to establishing public awareness is to view the urban forest as an ecosystem that includes people–forest interactions.

Fight, R.D.; Bolon, N.A.; Cahill, J.M. 1993. Financial analysis of pruning Douglas-fir and ponderosa pine in the Pacific Northwest. West. J. Appl. For. 10(1):58-61.

To determine expected financial returns from pruning, the authors incorporated data from recent lumber recovery studies of pruned and unpruned Douglas-fir and ponderosa pine into computer software, using lumber prices by grade, growth and yield data, the cost of pruning, and interest rates. Their financial analyses showed that the cost of pruning at which the investment would yield an expected 4% real rate of return is positive on sites where individual tree growth is fairly high, pruning is done as early as biologically possible given limitations on crown removal, and the harvest is 30 to 70 years after pruning.

Forboseh, P.F.; Pickens, J.B. 1996. A reservation value approach to harvest scheduling with stochastic stumpage prices. For. Sci. 42(4):465-473.

The authors formulated a multistand harvest scheduling problem, with stochastic stumpage prices, where demand constraints on the periodic yield of some products existed over a long planning horizon. They incorporated the underlying price uncertainty into their model as a stationary process with normally distributed deviations. In this article, they run a test case of two products, sawtimber and pulp, to illustrate their formulation. It was assumed that sawtimber was sold in an open market, while a certain periodic pulp harvest was required by contract to supply a mill at a set price. By maximizing the sum of current revenues and future reservation values, subject to yield constraints, the authors found that the model "optimally decides" when to harvest immature stands in response to low sawtimber prices, while retaining mature areas for future high prices. They assert that their results show significant improvements in present value and a much greater probability of feasibility compared with "traditional formulations."

Haight, R.G. 1990. Feedback thinning policies for uneven-aged stand management with stochastic prices. For. Sci. 36(4):1015-1031.

The author used an optimization model to determine feedback thinning rules for uneven-aged stand management, when the stumpage price forecast is a stochastic process. Periodic thinning was allowed to take place over a finite time horizon, with the objective of maximizing expected present value. For given assumptions, optimal-feedback thinning policies generated higher expected present value than did thinning strategies that ignored price fluctuations.

Harou, P.A. 1984. Evaluation of forestry programs: the with-without analysis. Can. J. For. Res. 14(4):506-511.

Applying the with-without marginal analysis (i.e., marginal benefit and costs), the author evaluated government-subsidized intensive forestry practice programs in the state of Massachusetts. The analysis considered the physical characteristics of stands treated under the program, the behavioral characteristics of the landowners participating in the program, and the sociopolitical environment underlying participants' behavior. The author found three factors that had a significant impact on net social marginal benefit: yield information on the managed and unmanaged (untreated) forests, the behavior of program participants, and the existence of forestry programs and laws related to forest management.

Hart, J.H.; Baughan, R.; Jennings, N.E. 1986. Economic impact of decay on black walnut. North. J. Appl. For. 3(3):116-118.

The authors calculated total volume, total loss in value caused by decay, total value, and total loss in value for 920 black walnut trees in five American states. They conclude that total loss of merchantable volume due to decay was 6% of total commercial volume.

Hof, J.G.; Field, R.C. 1989. True separable costs versus accounting-based separable costs in multiple-use forestry. For. Sci. 35(1):263-270.

The authors discuss the consistency or lack thereof between an economically correct definition of separable costs and a definition commonly applied to accounting data. Conditions were developed under which accounting separable costs would accurately reflect true separable costs and would provide lower bounds for true separable costs. In a test case involving multiple-use forestry, the hypothesized conditions were not met.

Jacques, R.; Fraser, G.A. 1989. The forest sector's contribution to the Canadian economy. For. Chron. 65(2):93-96.

The authors used input-output models of Statistics Canada to estimate the impacts of the forest sector on the economies of Canada and its provinces. They conclude that in 1980 close to 834 000 jobs depended upon economic activities within the forest sector.

Jones, J.R. 1987. Economic benefits of timber and productive forest land in British Columbia. For. Chron. 63(2):112-118.

Noting at the outset that his analysis does not include all nontimber forest values, the author states that the timber-harvesting and wood-processing industries provide the largest payroll in British Columbia, employing directly and indirectly over 20% of the total labor force. Wood-based products accounted for over 40% of all commodities manufactured in the province.

Kiker, C.F.; Putz, F.E. 1997. Ecological certification of forest products: economic challenges. Ecol. Econ. 20(1):37-51.

This is a methodological development paper. The authors start with the question, "Can markets play a role in mitigating the deleterious environmental and social impacts of forestry activities?" In addition to developing the concept of ecological certification, they analyze the relationships among the many actors and the relationship of the actors to the forest.

Kuuluvainen, J.; Karppinen, H.; Ovaskainen, V. 1996. Landowner objectives and non-industrial private timber supply. For. Sci. 42(3):300-309.

The purpose of the paper is to identify the link between ownership objectives and observed harvesting behavior by estimating a theoretical timber supply function. The authors used survey data for 146 Finnish forest owners and their timber sales for the period 1987 to 1991. They conclude that multiobjective owners harvest significantly more (in cubic metres per hectare per year) than other owner groups. Moreover, their results further indicate that the harvesting policy of the multiobjective owners can be described as maximizing present value, whereas the harvesting behavior of other (single-objective) groups seemed to reflect the effect of market imperfections.

Liechty, H.O.; Reed, D.D.; Mroz, G.D. 1988. An interim economic comparison of thinning treatments in a high site quality red pine plantation. North. J. Appl. For. 5(3):211-215.

With the objective of evaluating the effects of thinning intensity on the economic returns from a highly productive site (with index 81 at base age 50) of a red pine plantation, the authors calculated harvesting costs for seven types of thinning intensity treatments on experimental plots in the Western Upper Peninsula of Michigan. The economic value of each treatment, 10 years after the initial thinning, was determined from the calculated harvesting costs

and current product prices. Plots thinned to 60 ft^2 basal area per acre (ba/ac), 30% height, and 120 ft^2 ba/ac generated the highest economic returns, regardless of whether pulpwood, plywood, or sawtimber markets were used to determine returns.

Loomis, J.B. 1989. A more complete accounting of costs and benefits from timber sales. J. For. 87(3):19-23.

Emphasizing the need for including nontimber forest values and the costs associated with preserving and managing these values in accounting for the costs and benefits from timber sales, the author presents methodologies for and empirical estimates of losses in multiple-use forest management. The experimental site was a portion of the Gallatin National Forest in southwestern Montana. He recommends that comparing the discounted sum of the benefits to the discounted sum of the costs is a useful guide for decision making.

Luckert, M.K.; Bernard, J.T. 1993. What is the value of standing timber? Difficulties in merging theory with reality. For. Chron. 69(6):680-685.

The authors attempt to address the complex problems associated with stumpage pricing (appraisal). They discuss the various aspects of economic rent, including its concept, ways of collecting it (fixed, variable, or both), equitable distribution questions in competitive and concentrated markets, and impacts of a given tenure system. They recommend that decision makers consider all such issues in developing new stumpage fee (price) systems.

MacFarlane, D.D.; Zundel, P. 1995. The short-term economic impacts of the private woodlot silviculture program in New Brunswick. For. Chron. 71(3):282-287.

With the objective of assessing the socioeconomic impacts of silvicultural operations in private woodlots in New Brunswick, the authors used an "input-output simulation model." They conclude that the impacts were modest because of the province's heavy reliance on imports of consumer goods. Total impact multipliers for wages and salaries, gross domestic product at factor cost, and employment were found to be 1.23, 1.36, and 1.41, respectively.

Marcouiller, D.W.; Schreiner, D.F.; Lewis, D.K. 1995. Distributive economic impacts of intensive timber production. For. Sci. 41(1):122-139.

The authors' objective was to show the impact of production and processing of timber on different household income groups. Using social accounting matrices, they found that timber production potentials for three ownership categories and the forward linkages to wood-processing industries affect the incomes of three household income groups.

Mills, W.L., Jr. 1988. Forestland: investment attributes and diversification potential. J. For. 86(1):19-24.

Forests and forestland compete with all other assets for investment dollars. Because of the unique natural attributes and benefits of forests, forestry investment decisions are more complex than those for any other type of investment. The author identifies the most commonly recognized issues associated with any investment: rate of return and associated level of risk, liquidity or marketability, maturity or length of time the investment must be held, type of income (capital gain or ordinary) desired for tax purposes, amount of time available for managing investments, and possible protection from inflation or deflation. In closing, he argues that the advantages of forestry investments are inflation protection, tax benefits through income deferment, potential for multiple use of the forestland in question, potential for investment divers-ification, and solid rate of return for long-term investment.

Mitchell, K.J. 1988. SYLVER: modeling the impact of silviculture on yield, lumber value, and economic return. For. Chron. 64(2):127-131.

The author demonstrates applications of a system of analytical models, called SYLVER, to addressing the effects of silvicultural treatments on wood properties, standing yield, log quality, product value, and net present value. Information was gathered independently by several research organizations that were studying techniques to increase the yield and value of second-growth forests through intensive forest management and improved technology.

Murphy, G.; Pyles, M.R. 1989. Cost-effective selection of culverts for small forest streams. J. For. 87(10):45-50.

In this short article, the authors demonstrate the usefulness of a total discounted cost approach in analyzing alternatives for installing culverts. They recommend this approach as an appropriate decision criterion for assessing a cost-effective way of installing culverts. Total discounted cost is the sum of the original installation cost, the discounted annual maintenance costs, and the discounted expected costs of culvert failures that could be caused by peak flows.

Nautiyal, J.C.; Williams, J.S. 1990. Response of optimal stand rotation and management intensity to one-time changes in stumpage price, management cost, and discount rate. For. Sci. 36(2):212-223.

By providing a sound theoretical background, the authors show that soil expectation value is a reliable criterion for determining optimal rotation of a forest stand. They argue that valuable insight into the economics of timber production is obtained by analyzing the comparative statics of various systems. Comparative statics is an analysis of how a one-time shift in a particular parameter affects the value of a variable; this assessment is based on a comparison of the initial (preshift) and final equilibria. With their model, the authors conclude, a one-time increase in the discount rate would shorten the optimal rotation age.

Newman, D.H. 1987. An econometric analysis of the southern softwood stumpage market: 1950-1980. For. Sci. 33(4):932-945.

The author presents an aggregate regional econometric model of the southern markets for softwood solid wood products (combined lumber and plywood) and pulpwood stumpage. In deriving the stumpage supply equation, he took into account the possibilities of direct substitution by stumpage producers. Using three-stage least-squares regression techniques, the author found that solid wood stumpage is a complement in production with plywood; solid wood stumpage responds significantly more than pulpwood to changes in the final price of goods.

Newman, D.H. 1991. Shifting southern softwood stumpage supply: implications for welfare estimation from technical change. J. For. 89(2):31-37.

This paper estimates the economic benefits of increasing timber inventory through research and development in the southern softwood forests of the USA. The author analyzed the benefits accruing to consumers and producers of stumpage from increases in availability of softwood stumpage. He found that average total benefits were roughly equal between the pulpwood and the softwood (combined lumber and plywood) stumpage markets.

Omule, S.A.Y.; Paul, D.E.; Darling, L.M. 1994. Cost of pruning Douglas-fir in coastal British Columbia. For. Chron. 70(1):80-83.

Actual pruning and travel time was used as a measure of performance. To prune a young Douglas-fir to 6 m in one lift and two lifts took, respectively, 9.5 and 10.1 min in 14- and 18-year-old stands, with average spacing between trees of about 3 m on flat or 0% to 30% south-facing slopes in coastal British Columbia.

Pearse, P.H.; Lang, A.J.; Todd, K.L. 1986. The backlog of unstocked forest land in British Columbia and the impact of reforestation programs. For. Chron. 62(5):514-521.

In this article, the authors describe the reforestation policy of the British Columbia government and the "not satisfactorily restocked (NSR)" forestlands. They identy 1302 ha of NSR lands and suggest silvicultural strategies to rehabilitate all inadequately restocked forests.

Pearse, P.H.; Lang, A.J.; Todd, K.L. 1986. Economic priorities for reforesting unstocked forest land in British Columbia. For. Chron. 62(6):522-528.

The authors calculated the costs of reestablishing the accumulated backlog of unsatisfactorily stocked forestlands in British Columbia. Costs were calculated for each site class and type by region. They conclude that at 1983 silvicultural costs, it would require $1.3 billion to reforest all of the existing backlog.

Pedersen, L.; Chappelle, D.E. 1990. Economic contributions of the lake states' forest resources, 1982-1995. North. J. Appl. For. 7(1):10-13.

This paper assesses the socioeconomic role of the forest products industries in Michigan, Minnesota, and Wisconsin. The authors report that the forest products industries in these three states accounted for about 8% of the region's manufacturing sales, employment, and income for the period studied. In real terms, sales of forest products were forecasted to grow from $15 billion in 1982 to over $22 billion in 1995.

Perry, P.M.; Luckert, M.; White, W.; Adamowicz, W. 1998. Combining sharecropping and command control incentives in principal agent analysis: a forestry example. J. For. Econ. 4(3):267-279.

The authors developed a model to show that optimal command and control penalties might be set when firms have some equity in future crops. They concluded that as stumpage collected increases, equity to the firm decreases, which causes the optimum penalty to increase. Furthermore, the authors found that, if a divergence in social and private time preference or nontimber benefits (or both) causes social values to be external to the firm, the optimum penalty might be adjusted to internalize these values.

Price, C. 1987. Further reflections on the economic theory of thinning. Q. J. For. 81(2):85-102.

Using the most recent price-size relationship and the criterion net discounted revenue, at a 5% discount rate, the author concludes that precommercial thinning is often justified, but that postcommercial thinning is not profitable. The cost of constructing access roads is a major cost element.

Price, C. 1988. One more reflection on the economic theory of thinning. Q. J. For. 82(2):37-44.

The author evaluates various intensities and timings of thinning and argues that precommercial thinnings might increase long-term profitability. Under a given price-size relationship, at moderate discount rates and for crops of at least average yield class, precommercial thinning appeared to be generally justified. But the author cautions that in the increasingly uniform crops that result from tree breeding and wider spacing, precommercial thinning is not viable. Moreover, removal of submarginal and suppressed trees is feasible on hygienic grounds for enhancing amenity values (or both). High-road cost, or withdrawal risk, might prohibit any thinning at all.

Puttock, G.D.; Prescott, D.M.; Meilke, K.D. 1990. Stumpage prices in Southwestern Ontario: a hedonic function approach. For. Sci. 36(4):1119-1132.

Because the timber used in the production of lumber in southwestern Ontario has several distinctive chemical and physical characteristics, the authors hypothesized that lump-sum price would reflect differences in these characteristics. They estimated hedonic price functions for timber in southwestern Ontario, using pooled time-series cross-section data from a large sample of timber sales. The authors conclude that volume, species composition, tree size, timber quality, and distance to the purchasing mill all affect lump-sum stumpage prices.

Reed, D.D.; Holmes, M.J.; Johnson, J.A. 1986. A 22-year study of stand development and financial return in northern hardwoods. North. J. Appl. For. 3(1):35-38.

To calculate stand development and financial returns from eight different cutting procedures, the authors used data from long-term experimental plots in Baraga, Mich. They conclude that economic return was greatest in the most severe diameter-limit cuts (5, 12, and 16 in. [12.5, 30, and 40 cm]). But they caution that achieving those high initial returns might preclude any further returns for an extended period.

Rideout, D.; Hof, J. 1987. Cost sharing in multiple use forestry: a game theoretic approach. For. Sci. 33(1):81-88.

The authors applied game theory to the problem of joint cost allocation in forest management. They defined the bounds (limits) to cost allocations. They conclude that allocations consistent with the logic of game theory define a rational or Pareto-efficient core. This core is equivalent to a full set of separable costs and hence provides consistency with earlier literature on water resources, which was based on cost separability.

Rollins, K.; Forsyth, M.; Bonti-Ankomah, S.; Amoah, B. 1995. A financial analysis of a white pine improvement cut in Ontario. For. Chron. 71(4):466-472.

The authors used standard financial analysis to provide insights into the effects of an experimental improvement cut, designed to release understory white pine and initiate a shelter wood system. Highest value of net present value of benefits was the criterion they used for making decisions on the timing of harvesting. They conclude that the improvement cut increased the net present value of benefits per hectare of treated stands.

Romm, J.; Tuazon, R.; Washburn, C. 1987. Relating forestry investment to the characteristics of nonindustrial private forestland owners in northern California. For. Sci. 33(1):197-209.

The authors used logit regressions to relate characteristics of nonindustrial private forest landowners to the probability of forestry investment in northern California. Full-time residence, high income, and young age were found to be the most significant determinants of forestry investment by these landowners in general. Interestingly, absentee ownership, middle income, and old age were the most significant predictors of no investment.

Rouck, K.B.; Nelson, J.D. 1995. Timber supply and economic impacts associated with sustained yield unit size. For. Chron. 71(5):647-656.

A spatial forest planning model was used to examine the economic and environmental implications of various sizes of sustainable yield units. Harvests for a timber supply area in British Columbia were calculated using four sizes of sustainable yield units. Increases in costs of constructing and maintaining access roads and of delivered wood were observed as the size of sustainable yield units increased.

Routledge, R.D. 1987. The impact of soil degradation on the expected present net worth of future timber harvests. For. Sci. 33(4):823-834.

The author developed a dynamic programming algorithm, which permits the assessment of direct, long-term losses associated with destructive logging practices, and made adjustments to the Faustman formulation to account for soil degradation. His sample calculations reveal the crucial role that discount rate plays in determining optimum rotation ages.

Schallau, C.H.; Maki, W.R. 1983. Interindustry model for analyzing the regional impacts of forest resource and related supply constraints. For. Sci. 29(2):384-394.

The authors describe a simple, straightforward adaptation of the conventional Leontief interindustry model to analyze changes in the supply of primary inputs. They used data for the Douglas County, Ore., economy to illustrate the use of supply multipliers. First, they used the supply model, in conjunction with the demand model, to contrast the total, including induced, effects of importing logs and increasing the local timber supply, by departing from an even-flow supply policy. Because they believed that public timber supply policies affect Douglas County's investment climate, they analyzed the economic effects of capital funds flowing from, as compared to funds flowing into, the county. In conclusion, the authors advise that an input-output model merits careful consideration and use by forest economists.

Shyamsundar, P.; Kramer, R.A. 1996. Tropical forest protection: an empirical analysis of the costs borne by local people. J. Environ. Econ. Manage. 31(2):129-144.

Contingent valuation was used to value tropical forest resources for rural populations in Africa. Welfare losses from land-use restrictions associated with a newly established national park in Madagascar were estimated with a willingness-to-accept format. Because the authors believed that the local economy's cash flow was insufficient, their contingent valuation question was denominated in baskets of rice. They conclude that contingent valuation can be successfully applied to rural households in a developing country and that there exists a systematic association between various socioeconomic variables and the expressed willingness to accept compensation for foregone land use.

Sullivan, J.; Gilless, J.K. 1990. Hybrid econometric/input-output modeling of the cumulative economic impact of national forest harvest levels. For. Sci. 36(4):863-877.

The authors used a combination of econometric and input-output methods to assess the multiforest personal income impacts of timber harvesting activities on regional economies in northern California. The importance of a combined assessment is demonstrated with data from the El Dorado and Shasta-Trinity national forests. Depending upon the timber harvest levels of other national forests in the area, projected changes in personal income resulting from a change in harvest level for either forest varied by as much as 27%.

Wagner, J.E.; Rideout, D.B. 1991. Evaluating forest management investments: the capital asset pricing model and the income growth model. For. Sci. 37(6):1591-1604.

Combining an income growth model with a nominal and real capital asset pricing model, the authors evaluated two alternative management regimes, using a simulation of two regulated ponderosa pine plantations in the Pacific Northwest of the United States. Their simulation highlighted five findings: both nominal and real results showed that a thinning investment did not reduce financial variability as measured by the beta index of the capital asset pricing model; the beta indexes indicated that the returns to the forestry assets examined were insensitive to nominal or real changes in returns of the market portfolio; a majority of the

total variability of the returns of the two forestry assets was diversifiable; the forestry assets examined were identified as inferior inflation hedges; and there was no statistical difference between the nominal and the real beta indexes of the forestry assets examined.

White, W.A. 1991. Economics and sustainable forest development: the case of soil degradation. For. Chron. 67(1):19-22.

Within the context of soil degradation, the author discusses the issues associated with environmental quality. He uses the concept of production possibility frontier to demonstrate the possibilities of assessing the differences between production efficiency, financial efficiency, and economic efficiency. The author concludes that production of forest products decreased in the presence of ground rules for forest harvest.

Williams, J.S.; Nautiyal, J.C. 1990. The long-run timber supply function. For. Sci. 36(1):77-86.

The authors derived a long-term equivalent for annual timber supply functions from two versions of the Faustman model. From their theoretical perspectives, they conclude that, in the two cases, the expression for the equivalent annual quantity of timber supplied was identical. A second main result, according to the authors, is the mathematical proof that the slope of the long-run timber supply curve remained positive along its entire length, when establishment costs were fixed and variable. Their theoretical conclusions are supported by the results of some calculations they conducted using well-established yield function for jack pine in Ontario.

Yin, R.; Newman, D.H. 1996. The effect of catastrophic risk on forest investment decisions. J. Environ. Econ. Manage. 31(2):186-197.

Using a forest-level model, where the output price was specified to follow a stochastic process, the authors analyzed the effect of catastrophic risk on forest investment decisions. Moreover, they incorporated a Poisson jump process to reflect the occurrence of catastrophic events. They conclude that the presence of catastrophic risk would always would in a reduced production value but an increased investment threshold for a forestry project.

Yoshimoto, A. 1996. A new stochastic model for harvesting behavior with application to nonstationary forest growth and supply. Can. J. For. Res. 26(11):1967-1972.

The author proposes a new stochastic model to predict harvesting behavior. His model is based on a generalization of Gentan probability theory, which was introduced in the early 1960s in Japan. Harvesting behavior was predicted by searching for felling probabilities of forest stands over different age classes, where the tree diameter was assumed to be the only factor affecting a forest owner's decision to harvest. The author proposes that, using a stationary growth function, the stochastic model can be flexible enough to incorporate not only growth in tree diameter, but also volume growth of the forest stand and present net worth, to predict a forest owner's harvesting behavior.

Zhang, D.; Pearse, P.H. 1996. Differences in silvicultural investment under various types of forest tenure in British Columbia. For. Sci. 42(4):442-449.

Basing their postulates on the conventional theory of capital, the authors developed a silvicultural investment model and assessed the relationship between forest tenure and silvicultural investment. They used data on silvicultural activities and expenditures for a large number of recently logged tracts in British Columbia. They found that silvicultural investment was correlated with security of tenure and that the level of investment under the most secure form —private land—was more than 67% greater than that under the least secure form—the forest licenses.

Biodiversity

With "biodiversity" as a catch-all term, an extensive body of literature has been mushrooming recently. In addition to what is available in libraries, extensive collections of bibliographies on the subject are now available at various Web sites. For example, the Department of Agricultural and Resource Economics of Oregon State University (OSU) has a comprehensive record under the title *Bibliography on the Conservation of Biological Diversity: Biological/Ecological, Economic, and Policy Issues.*

In Canada, the International Institute for Sustainable Development, based in Winnipeg, Man. —among others—has a good collection of literature; although focusing on sustainable development, most of this literature deals with issues related to biodiversity. The Web site address of the institute is: <http://iisd1.iisd.ca/>. Accessed November 29, 2000.

The following annotations cover a small sample of the literature on the important subject of biodiversity, which has been extensively studied by hundreds of researchers.

Campbell, G.E.; Countryman, D.W. 1981. Comparing estimated wilderness costs among national forests. J. For. 79(9):605-607.

By developing marginal cost curves from linear programming models, the authors depict the relative wilderness costs for forests in the Willamette area of Oregon. Their objective is to assist managers in comparing trade-offs, making wilderness selection cost-effective, and isolating those forests where wilderness decisions have greater impact.

Flaaten, O. 1991. Bioeconomics of sustainable harvest of competing species. J. Environ. Econ. Manage. 20(2):163-180.

The authors applied the concept of maximum sustainable yield frontier (MSF) to a Gause model of competing species to examine the level of economic rent under various scenarios. They found that maximizing the present value of economic rent with costless harvesting and a positive discount rate implied optimal stock levels below the locus of MSF stocks. But maximizing economic rent with positive harvesting costs and a zero discount rate implied optimal stock levels above the locus of MSF stocks. Finally, the authors show that optimal steady-state stock levels are altered by changes in the exogenous discount rate, harvest prices, and harvest costs. They conclude that optimal harvesting might lead to harvesting one of two species at a loss.

Funtowicz, S.O.; Ravetz, J.R. 1994. The worth of a songbird: ecological economics as a post-normal science. Ecol. Econ. 10(3):197-207.

This article is a scientific commentary, published in the tradition of Ecological Economics for encouraging further critique, a valuable feature of this journal. Under the rubric "Commentary" the journal provides a forum for intellectual debate of important current issues. The authors present this article in that spirit, welcoming further debate and critique.

Gowdy, J.M.; McDaniel, C.N. 1995. One world, one experiment: addressing the biodiversity–economics conflict. Ecol. Econ. 15(3):181-192.

The authors base their arguments on the theory of self-organizing principles. They contend that the self-organizing principles of markets, which have emerged in human cultures over the past 10 000 years, are inherently in conflict with the self-organizing principles of ecosystems, which have evolved over the past 3.5 billion years. They clarify their arguments by stating that the rules governing the dynamics of ecosystems, within which all human activity takes place, are ultimately a function of biological laws, not a function of human-created economic systems. They further argue that the conflict between these systems is illustrated by the fact that economic indicators have shown vigorous growth during the last century, while a variety of environmental indicators have exhibited negative trends. In conclusion, they identify the causes for conflict between biological and economic activity and

suggest policy approaches that might enhance the chances for creating cultures that are economically and environmentally sustainable.

Guldin, R.W. 1980. Wilderness costs in New England. J. For. 78(9):548-552.

Asserting that it is a theoretically complete, direct social cost-accounting framework for use in considering wilderness designation proposals, the author presents a short description of an analysis methodology. He recommends its application instead of the one used by the United States Congress in the past. Testing his approach in four wilderness areas in Vermont and New Hampshire, he found that the costs (specifically opportunity costs) were sub-stantially higher than those estimated by Congress.

Gunatilake, H.M. 1995. An economic impact assessment of the proposed conservation program on peripheral communities in the Knuckles Forest Range of Sri Lanka. J. Sustain. For. 3(1):1-14.

This paper deals with two sets of conflicting interests in society: preservation of a forest area to maintain biodiversity and the immediate, negative socioeconomic impacts of that decision. The author analyzed this scenario in terms of a forest area called Knuckles Forest Range, which has been identified as a unique biological resource in Sri Lanka. He analyzed the socioeconomic impacts of the project, using data collected from 80 households in 48 villages on the periphery of the forest. He found nine components of the farming system that use resources from village and forest resource systems. Of these, cardamom production, shifting cultivation, and extraction of non-timber forest products were based on forest resources, while livestock activities used resources from both the forest and the agricultural systems. Further, the communities were heavily dependent on forest resources, which accounted for 58.3% of average total income (wealth) and 59.4% of average monetary income. The average annual income loss per family was estimated to be US$817.50, if the conservation program were to restrict the use of forest resources completely.

Hrubes, R.J. 1984. Can roadless areas be allocated to wilderness without loss in timber harvest capability? J. For. 82(6):369-372.

To investigate whether loss of timber harvest capability in areas designated for wilderness could be compensated by increased production on remaining lands in the USA, the author developed simulated harvest schedules for a western national forest with FORPLAN, a linear program planning model. A central feature of the schedule is the removal of environmentally and politically induced constraints, which limit timber management on the lands left for timber production. He concludes that short-term allowable harvest could be maintained even if significant acreages were removed from production, but with an unavoidable compromise in terms of long-term harvest capability.

Loomis, J.B.; Loft, E.R.; Garrison, B.A. 1995. An economic assessment of hardwoods as habitat components for black-tailed deer in northern California conifer trees. J. For. 93(8):41-45.

The authors make inferences and show how to quantify the benefits to deer hunters of maintaining more than the minimum non-commercial stands of oak in forested areas of northern California. They argue that maintaining oak retention above current levels does have costs. Commercial timber yields may be reduced when increased oak retention imposes opportunity costs on timber operations through competition with softwoods and reduction in growing space.

Mattsson, L. 1990. Moose management and the economic value of hunting: towards bio-economic analysis. Scand. J. For. Res. 5:575-581.

Acknowledging that moose management requires knowledge about how the economy of moose, in terms of costs and benefits, responds to alterations in the moose population, the

author focused his empirical work on the value of moose hunting. He dealt with the question of how this value, including aspects of recreation value as well as meat, changed with changes in moose population density. He found that hunting value increased with an increase in moose population, but at a decreasing rate and with variation from one location to another.

Merrifield, J. 1996. A market approach to conserving biodiversity. Ecol. Econ. 16(3):217-226.

Focusing on the impacts of the *Endangered Species Act* in the USA, the author describes a market mechanism for simultaneously internalizing the social cost of eliminating especially scarce habitat and the social benefits of protecting it. For land-owners with low-value, nonhabitat land uses, the author contends that the market mechanism transforms habitat from a major liability into a money-making asset. For landowners with high-value, nonhabitat uses, the market mechanism would be a very attractive alternative to the current slow and expensive case-by-case consultation process. Finally, the author suggests that environmentalists will appreciate the market process, because it is less subject to politicization, while assuring that agreed-upon, safe biological minimums cannot be violated.

M'Gonigle, M.; Gunton, T.; Fletcher, C.; McAllister, M.; MacKnight, D. 1992. Comprehensive wilderness protection in British Columbia: an economic impact assessment. For. Chron. 68(3):357-364.

For assessing the effects of a comprehensive wilderness proposal on the British Columbia forest industry, the authors developed an impact assessment model. They found that the overall impacts were relatively small, involving a 3.5% reduction in the provincial annual allowable cut, with regional impacts ranging from 1.9% to 5.2%. They discuss some ways to offset these negative impacts, because they believe that the ability to offset loss of employment influences significantly the feasibility of wilderness designations. However, they recommend further quantitative modeling and analysis that integrate geographic information systems and input–output procedures.

Montgomery, C.A.; Pollack, R.A. 1996. Economics and biodiversity: weighing benefits and costs of conservation. J. For. 94(2):34-38.

In this short article, two distinguished professors of economics succinctly present their ideas regarding the role of economics in assessing trade-offs between conservation and rational harvest of natural resources. They contend that economists often exasperate environmentalists when they view biodiversity as only one desirable goal among many and insist that it must compete for public budgetary resources with other goals, such as feeding, housing, and clothing the human population, which has doubled since the 1950s. Although the principal cause of the imminent extinction of some species is believed to be habitat alteration associated with the growth and economic activity of the human population, the authors argue, applying economic theory and techniques, that competition for resources inevitably involves painful trade-offs.

Rubin, J.; Helfand, G.; Loomis, J. 1991. A benefit-cost analysis of the northern spotted owl: results from a contingent valuation survey. J. For. 89(12):25-30.

Like the previous ones, this article deals with the issue of trade-off analysis. It specifically addresses the impacts of the 1973 *Endangered Species Act* in the USA. The authors highlight the importance and implications of the act by stating that no conflict has raged as hotly as the debate over the northern spotted owl in the Pacific Northwest. They report that old-growth timber stands, the owl's habitat, are highly valued for their products, and that because the economies of that region rely heavily on timber harvesting, and because protecting owl habitat means reducing the annual allowable cut, protection of the owl

could have serious economic consequences. On the other side of the debate is the spotted owl and the old-growth ecosystem. Current habitat on all lands was estimated to support 1743 owl pairs in Washington, Oregon, and California. The owl is considered a "threatened species" under the *Endangered Species Act*; without additional protection, its population will probably become extinct under current management strategies. The authors conclude, from their contingent valuation survey, that the economic benefits received much less attention than the amenity values. People were willing to pay more for protection of the spotted owl and the associated ancient forest ecosystem.

Tacconi, L.; Bennett, J. 1995. Economic implications of intergenerational equity for biodiversity conservation. Ecol. Econ. 12(3):209-223.

The authors start with a recognition statement: "The rights of future generations to enjoy sustainable development have been formally recognized internationally. This has important implications for the economic analysis of biological diversity, which, as an integral attribute of natural capital, is of critical importance to both current and future generations." On the basis of their empirical findings, the authors recommend an incremental and adaptive learning process for using and distributing natural resources "to ensure the well-being of future generations." They suggest three levels of intergenerational equity for implementation purposes: extensive, intermediate, and minimal. Conceptually, decisions about conserving biodiversity by establishing protected area systems should be based on ethical grounds, instead of being based on the results of economic analysis. They argue that economic issues would necessarily be answered in the affirmative on the basis of the interests of future generations. At the practical level, however, an economic analysis for protected area systems should be used to contribute to a holistic approach in identifying the areas to be protected, investigate the most cost-effective way of carrying out the initiative, assess the intragenerational equity outcomes, and consider the institutional features relevant to the success of the conservation initiative.

Takekawa, J.Y.; Garton, E.O. 1984. How much is an evening grosbeak worth? J. For. 82(7):426-428.

This article is an economic analysis of biological control of the western spruce budworm—the economics of bird predation, to be exact. The authors assert that birds consume large numbers of the western spruce budworm, a forest insect that defoliates economically valuable stands. They estimated the economic value of bird predation on two stands in north-central Washington by substituting the cost of spraying with insecticides to produce the same mortality rate as birds cause. They found that spraying would cost \$1820/km^2 annually over a 100-year rotation. They contend that calculation of this type could be used to appraise the value of individual predator species, such as the voracious evening grosbeak, to evaluate the cost-effectiveness of biological control with birds, and to assess silvicultural treatments and other practices that affect both bird and insect populations.

Teeguarden, D.E. 1981. A method for designing cost-effective wilderness allocation alternatives. For. Sci. 27(3):551-566.

The author used a linear programming model for selecting a least-cost set of wilderness areas from the RARE II (Roadless Area Review and Evaluation) roadless area inventory for California. From this, he derived a wilderness supply cost function. Considering wilderness opportunity cost as the foregone resource value from nonwilderness management, he developed a model that deals with wilderness allocation alternatives at the regional level as well as with secondary goals, such as ecosystem representation and geographical location of wilderness units. From empirical results, he concludes that the marginal cost of additional wilderness in dollars per acre and per visitor day was relatively negligible up to about 2 million acres. But opportunity cost increased to a maximum of US\$74 per potential visitor day if the RARE II areas received the same average level of use as existing wilderness

areas. Ecosystem representation goals added to opportunity costs, but diminished to zero for a wilderness allocation goal exceeding 3 million acres.

Tisdell, C. 1990. Economics and the debate about preservation of species, crop varieties and genetic diversity. Ecol. Econ. 2(1):77-90.

Giving particular consideration to priorities as set out in the World Conservation Strategy, the author discusses the ways in which cost-benefit analysis and the safe minimum standard approach can be used. He compares different criteria, assuming that there is an absolute upper constraint on the amount of resources available for conserving species. Continuing his theoretical argument, he presents a philosophical view on the importance of the burden of proof in the debate between conservation and nonconservation. He concludes by stressing that recent economic thought has swung more toward the view that the burden of proof should rest on those seeking to carry out activities that may extinguish a species.

van Kooten, G.C. 1995. Economics of protecting wilderness areas and old-growth timber in British Columbia. For. Chron. 71(1):52-58.

With the objective of examining the costs and benefits of preserving old-growth forests in British Columbia, the author compared estimates of the present worth of old growth in timber production with the measurable nontimber benefits of preserving old growth. He concludes that for reasonable amounts of nontimber values, the current levels of wilderness protection (i.e., old-growth preservation) were more than adequate on the coast. He adds that an increase in wilderness area of 1.6 million ha might be economically justifiable.

Climate Change

Adams, R.M. 1989. Global climate change and agriculture: an economic perspective. Am. J. Agric. Econ. 71(5):1272-1279.

The objective of this paper is to provide an economic perspective on the strategic measures that governments might take to reduce greenhouse gases. The author presents: an overview of contemporary economic thinking on some central research issues related to climate change and an assessment of whether economic adjustments are likely to soften or offset the negative effects suggested by recent research. His qualitative discussion draws heavily upon a sizable and growing economic literature on global climate change.

Binkley, C.S.; Van Kooten, G.C. 1994. Integrating climatic change and forests: economic and ecologic assessments. Clim. Change 28(1):91-110.

Effective policies for dealing with anticipated climate change must reflect two-way interactions between climate, forests, and society. Stating that the ordinary problems of managing forests challenge decision makers to integrate ecologic, economic, and social information, the authors describe the problems and possible solutions associated with the structure and function of three complex and interlocked systems: climate, the terrestrial biosphere, and the forest sector (broadly defined to include timber, wildlife, water, recreation, and other environmental services).

Brække, F.H.; Lunnan, A.; Rørstad, P.K. 1994. Cost effectiveness of greenhouse gas reduction and profitability of forest production on old drained fields in Norway. Scand. J. For. Res. 9:83-90.

This empirical work is based on data collected from trial plots on oligotrophic peatland. The authors' objectives were to

evaluate the validity of some biological parameters used for economic modeling, to test the profitability of peatland afforestation by *ex post* analysis of middle-aged stands, to calculate the cost-effectiveness of the afforestation program, and to compare and discuss the results from this *ex post* calculation with *ex ante* results from previous research conducted by others. The authors used three decision-making criteria: internal rate of return, net present value, and cost effectiveness. They conclude that it would be financially viable to carry out afforestation programs to increase absorption of atmospheric (greenhouse) gases, such as carbon dioxide, nitrous oxide, and methane.

Brown, K.; Adger, W.N. 1994. Economic and political feasibility of international carbon offsets. For. Ecol. Manage. 68:217-229.

The authors discuss initiatives intended to enhance natural carbon sinks. The major focus is on forests, a major carbon sink. It is believed that more afforestation and conservation of existing forests are required to reduce net emissions of greenhouse gases. The authors argue that theoretically the international offset of emissions may lead to resource saving and that forest conservation, as opposed to afforestation, may bring about many other benefits. In contrast to the intentions put forward later in the Kyoto Protocol, signed on 10 December 1997, the authors conclude that international contracts are unlikely to be feasible or to contribute significantly to controlling greenhouse gases, because of the difficulties associated with monitoring, enforcement, scientific uncertainties, and the implicit change in property rights involved in "selling" carbon sequestration rights.

Daily, G.C.; Ehrlich, P.R.; Mooney, H.A.; Ehrlich, A.H. 1991. Greenhouse economics: learn before you leap. Ecol. Econ. 4(1):1-10.

This article is an analytical commentary on the consequences of global warming. It is mainly a critique on the stance of the USA on climate change. The authors start their analysis with the following enlightening statement:

"In virtually no area of the human enterprise is there more uncertainty than in matters of national defense. How well armed, trained, allied, clever, and persevering an aggressor might be is often uncertain. Moreover, the nature of an attack—the direction of and with what weapon and strategy a strike might be made—is normally deliberately concealed. In response to this uncertainty, the United States has military bases around the world, nuclear submarines patrolling the remotest parts of the oceans, missiles poised to strike against any land or airborne target, and military satellites orbiting the entire planet. Thousands of highly trained intelligence officers filter through the minutia of activities of perceived enemies and prepare elaborate contingency plans. The U.S. has carefully negotiated, verifiable international arms control treaties. Finally, it has developed the most advanced and sophisticated weapons and communications technology to serve these functions. The cost of this form of military security consumes about a third of the United States' federal budget."

This statement is followed by the authors' qualitative assessment of the impacts of global warming on food production, coastal land security, natural ecosystems, human environments, energy and industry, and the global commons, in which they refer to the fact that "the world is now so interconnected politically, economically, and especially through the atmosphere that for the rich to count on a lifeboat escape from the consequences of buildup of greenhouse gases is a sheer folly."

Drosdowsky, L.M.; Maunder, W.J. 1993. Australian industrial and commercial response to climate change: risk analysis and communication under uncertainty. Clim. Change 25(3):247-254.

Focusing on Australia, the authors attempt to provide a qualitative description of the pros and cons of global warming. They argue that any consideration of the impact of climate change on Australian urban, industrial, and manufacturing activities must recognize several facts. First, human-induced climate change has yet to be satisfactorily quantified. Second, any

climate change will occur on local, regional, and global scales, and regional changes could be significantly different in magnitude and character from one region to another. Third, any effects caused by "climate change" will either accentuate or dampen effects caused by local climate variation.

Green, C. 1992. Economics and the 'greenhouse effect.' Clim. Change 22(4):265-291.

At the outset, the author acknowledges the growing scientific and public concern that increasing concentrations of greenhouse gases in the atmosphere will produce global warming and other climatic changes. But, although economic activity has been identified as the main source of greenhouse gas emissions, information and incentive problems make it difficult to translate concern about global warming into economic behavior and public policy conducive to reducing emissions. The author considers the economic effectiveness and efficiency of three sets of strategies: near-term (a carbon tax), intermediate term (afforestation and energy efficiency), and long-term (new non-fossil-fuel technologies). He acknowledges the shortcomings and limitations of each strategy.

Jenkins, T.N. 1996. Democratizing the global economy by ecologicalising economics: the example of global warming. Ecol. Econ. 16(3):227-238.

The author's objective is to show that continued reliance on an unreconstructed neoclassical economic model of human progress is largely responsible for economic development that is both unsustainable and undemocratic. Using the issue of global warming as an illustration, the author argues that the "ecologicalization" of the economics discipline challenges the foundations of this model. In closing, he asserts that the damage of global warming is directly attributable to economic activity, that the benefits of economic growth go to the developed countries, and that the disbenefits, in terms of environmental damage, are borne by the developing countries.

Joyce, L.A.; Mills, J.R.; Heath, L.S.; McGuire, A.D.; Haynes, R.W.; Birdsey, R.A. 1995. Forest sector impacts from changes in forest productivity under climate change. J. Biogeogr. 22:703-713.

The authors present a framework to link four approaches—climate change scenarios, an ecosystem model, a forest sector model, and a carbon accounting model—for analyzing the impacts of increased levels of carbon dioxide and climate change on forest ecosystems. Four climate change scenarios were used to estimate net primary productivity for forests in the USA. Changes in net primary productivity were estimated with a terrestrial ecosystem model, which uses spatially referenced information on climate, soils, and vegetation to estimate carbon and nitrogen fluxes and pool sizes within an ecosystem at the continental scale. Changes in net primary production were used to modify timber growth within the aggregate timberland model (ATLAS), which is part of the forest sector model (TAMM-ATLAS) used by the United States Department of Agriculture Forest Service to examine timber policy issues. A national carbon model (FORCARB) was used to translate the changes in timber inventories into changes in the amount of carbon stored on private timberland. The authors conclude that forest sector and results in changes in land use and timber consumption. Long-term carbon storage indicated that the private timberlands would be a source of carbon dioxide in all but the most optimistic climate change scenario.

Kokoski, M.F.; Smith, V.K. 1987. A general equilibrium analysis of partial-equilibrium welfare measures: the case of climate change. Am. Econ. Rev. 77(3):331-341.

A computable general equilibrium model is used to show that partial-equilibrium welfare measures can give good approximations of the true welfare changes for large exogenous changes. With partial-equilibrium welfare measures, relatively large single-sector impacts can be adequately measured with compensating variation. According to the model, climate change would cause large and mixed price effects with both

increases and decreases in carbon dioxide induced climate change.

Kolstad, C.D. 1996. Learning and stock effects in environmental regulation: the case of greenhouse gas emissions. J. Environ. Econ. Manage. 31(1):1-18.

This paper looks at the optimal way of regulating the greenhouse gases that cause global climate change, by focusing on uncertainty and learning. A stochastic model of climate-economy interactions is used, as well as the results of the conflict between postponing control until more is known and acting immediately before irreversible climate change occurs. The author concludes that there was no significant stock effect associated with greenhouse gas accumulation.

Lempert, R.J.; Schlesinger, M.E.; Bankes, S.C. 1996. When we don't know the costs or the benefits: adaptive strategies for abating climate change. Clim. Change 33(2):235-274.

Most quantitative studies of climate change policy attempt to predict the plan for reducing greenhouse gases that will have the optimum balance of long-term costs and benefits. However, these authors found this "traditional approach to be unreliable," because of the large extent of uncertainties associated with climate change. To alleviate the problem, they constructed "a large uncertainty space" that included the possibility of large or abrupt climate change or of technology breakthroughs that would radically reduce projected abatement costs (or any combination of these). The authors used computational experiments on a linked system of climate and economic models to compare the performance of a simple adaptive strategy.

Lewis, D.K.; Turner, D.P.; Winjum, J.K. 1996. An inventory-based procedure to estimate economic costs of forest management on a regional scale to conserve and sequester atmospheric carbon. Ecol. Econ. 16(1):35-49.

The authors use an inventory-based procedure to estimate the forest management costs of carbon conservation and sequestration. To illustrate, they examine four policy-based scenarios projected in the carbon budget of the USA. This procedure is applicable to large geographic scales; however, the scale requires consideration of forest inventory; integration of biological, social and economic components; and distribution of impacts. These scenarios show that the inventory-based procedure fulfills the requirements for estimating forest management costs to conserve and sequester atmospheric carbon.

Mcconnell, K.E. 1997. Nonmarket valuation and the estimation of damages from global warming. Clim. Change 37:121-139.

The author measured the economic values of nonmarket damages associated with climate change. The additional question of whether the guidance for nonmarket valuation in the Principles and Guidelines (the manual for resource planning of the United States Army Corps of Engineers) is suitable for an era of climate change is also raised and assessed. Overall, the paper attempts to define the damages of global warming, measure the costs and benefits of policy measures taken to control global warming, and describe the techniques used for valuing the nonmarket services of the natural environment.

Meyer-Abich, K.M. 1980. Socioeconomic impacts of CO_2-induced climatic changes and the comparative chances of alternative political responses: prevention, compensation, and adaptation. Clim. Change 2(4):373-385.

The author describes climate change on five conceptual levels: climate parameters (observable atmospheric conditions, described by climatic statistics), environmental potential (characterized by the four elements: soil, water, air, and energy conditions), human material (economic) activity (e.g., agriculture, transportation, manufacturing, and construction), social interaction (e.g., employment and unemployment, migration, social conflicts, and cultural shifts for which psychology and sociology can give a useful analytical framework), and political process (policy measures, such as legislative action, research and development programs, economic incentives or restrictions, and international policies). He concludes that prevention of climatic change by changing human economic behavior or compensation for climatically detrimental effects by technological fixes is not necessarily better than adaptation. In other words, adaptation is the most rational option and requires the least marginal action.

Miller, K.A.; Glantz, M.H. 1988. Climate and economic competitiveness: Florida freezes and the global citrus processing industry. Clim. Change 12(2):135-164.

The paper is a descriptive-comparative analysis of the citrus-processing industries of Florida and Brazil. Three objectives are outlined: to describe the role of climate change in the development of Florida's citrus industry; to use this industry to show how extreme meteorological events can and do affect human activities; and to identify the role of meteorological events in Florida in the comparatively rapid development of Brazil's orange juice industry. The authors pose three questions: Is the success of the Brazilian citrus industry integrally linked to Florida's climate, or specifically to Florida's freeze events? To what extent have Florida's freezes accounted for the rapid expansion of Brazil's citrus industry? Might that expansion have occurred even in the absence of Florida's recent anomalous series of freeze events? In attempting to answer these questions, the authors describe only trends in raw data on production and harvest with respect to climatic variations in Florida and Brazil. They conclude that the impacts of recent freezes in Florida explain only part of the story of the interaction between climate variability on one hand and the relationship between the citrus industries of Florida and Brazil on the other.

Naughten, B.R. 1993. Climate change, Australian impacts and economic analysis. Clim. Change 25(3):255-270.

The paper focuses only on the contribution of economic analysis to solving problems of adjustment to climate change. That is, it does not deal with the economics of emission abatement policies. It distinguishes between descriptive and prescriptive forms of economic analysis. In the case of prescriptive analysis, the author makes a further distinction between equity and efficiency cases for government intervention. Intergenerational and interregional equity effects of climate change are examples of the former concern. The author concludes that both climate change and adjustment responses are likely to lead to "market failures."

Nordhaus, W.D.; Yang, Z. 1996. A regional dynamic general-equilibrium model of alternative climate-change strategies. Am. Econ. Rev. 86(4):741-765.

This study deals with the impacts of different changes in strategic policy in response to climate change by selected developed and less developed countries. Pure market solutions, "efficient" cooperative outcomes, and noncooperative equilibria are the policy options compared. The authors found that the cooperative strategic policy showed much higher levels of emission reduction than did noncooperative strategies; that there were substantial differences in the levels of controls in both the cooperative and noncooperative

policies among different countries; and that high-income (developed) countries might be the major losers from cooperation.

Parry, M.L.; Magalhaes, A.R.; Nih, N.H. 1992. The potential socio-economic effects of climate change: a summary of three regional assessments [document on-line]. United Nations Environment Programme, Nairobi, Kenya. Accessed November 29, 2000. <http://www.ciesin.org/docs/004-149/004-149.html>.

This report summarizes the main conclusions of three regional studies of the potential impact of climate change undertaken by national governments with the support of the United Nations Environment Programme. The three regional studies were conducted in Brazil; in Indonesia, Malaysia, and Thailand; and in Vietnam. Various assessment techniques were used. In Brazil, the emphasis was on identifying the effects that can occur now as a result of the present variability of climate from year to year and from season to season. Thus, impacts of climatic variation were considered useful indicators of potential future effects of long-term climate change. In contrast, the Indonesia–Malaysia–Thailand study took the current best estimate of possible future climate conditions, which was used to evaluate economic implications. The study in Vietnam adopted an approach between these two, assuming likely long-term changes in climate and describing their potential effects.

Phillips, T.P.; Forster, B.A. 1987. Economic impacts of acid rain on forest, aquatic, and agricultural ecosystems in Canada. Am. J. Agric. Econ. 69(5):963-969.

The authors state at the outset that their paper is restricted to a review of the economic impacts of acid rain on aquatic, forest, and agricultural ecosystems of Canada. They classify pollutants as primary and secondary and discuss their respective impacts on forest ecosystems, aquatic ecosystems, and agricultural systems. The primary pollutants are identified as sulfur dioxide and nitrogen dioxide, while the secondary pollutants are mainly ozone, acid, and peroxyacetyl nitrate. The authors' conclusions on the economic impacts of these pollutants are based on disparate—in some respects contradicting—literature and simple quantitative approaches.

Schroeder, P. 1992. Carbon storage potential of short rotation tropical tree plantations. For. Ecol. Manage. 50:31-41.

Although he does not extend his experiment into an empirical analysis of the socioeconomic functions of forests as carbon sinks, the author provides an informative analysis from the biological perspective. He states that forests represent a major sink for carbon and play an important role in the global carbon cycle. Not only do forests contain a huge amount of carbon, but they also actively exchange it with the atmosphere for oxygen. Thus, expanding the world's forests presets an opportunity to increase the terrestrial carbon sink and slow the increase in atmospheric carbon dioxide concentration. The author believes that the tropical zones of the world seem particularly attractive for afforestation, because of the high forest yield that can be attained there.

Schelling, T.C. 1992. Some economics of global warming. Am. Econ. Rev. 82(1):1-14.

Schelling, a well-known economist, explains the magnitude of the social and economic consequences of global warming (the greenhouse effect). In his words, "The greenhouse effect itself is simple enough to understand and is not in any real dispute. What is in dispute is its magnitude over the coming century, its translation into changes in climates around the globe, and the impacts of those climate changes on human welfare and the natural environment. These are beyond the professional understanding of any single person. The sciences involved are too numerous and diverse. Demography, economics, biology, and the technology sciences are needed to project emissions; atmospheric chemistry, oceanography, biology, and meteorology are

needed to translate emissions into climates; biology, agronomy, health sciences, economics, sociology, and glaciology are needed to identify and assess impacts on human societies and natural ecosystems. And those are not all."

Schelling, T.C. 1996. The economic diplomacy of geoengineering. Clim. Change 33(3):303-307.

The paper is a succinctly presented scientific essay on how to develop a global policy framework on climate change. The author starts with justifying statements on the complexity of the issues associated with climate change and the ambiguity of "geoengineering," a new term for which a definition is still needed. However, it is the author's belief that the term might simplify greenhouse policy, transforming it from an exceedingly complicated regulatory regime to a problem in international cost sharing, a problem that society is familiar with. Putting things in the stratosphere or in orbit can probably be done by "exo-national" programs, independent of the behavior of populations, without national regulations or incentives, and independent of universal participation. Such an approach will only involve deciding what to do, how much to do, and who is to pay for it.

Schimmelpfennig, D. 1996. Uncertainty in economic models of climate-change impacts. Clim. Change 33(2):213-234.

The author argues that uncertainty is poorly represented in existing studies of the impacts of climate change. He describes the methods that have been used to characterize uncertainty in the literature, and particularly the deterministic economic models. He then highlights the limitations of the studies he reviews by pointing out the restrictive nature of their objectives, which focus on specific scenarios and randomization of study variables and which concentrate on behavior rather than impacts.

Sedjo, R.A. 1989. Forests to offset the greenhouse effect. J. For. 87(7):12-15.

Focusing on the greenhouse effect, the author examines the potential of forests to delay global warming. Included in this article are estimates of land area and resources required to establish forest plantations to offset expected increases in atmospheric carbon. According to the author, such plantations can be expected to delay global warming by 30 to 50 years.

Smith, V.K. 1982. Economic impact analysis and climate change: a conceptual introduction. Clim. Change 4:5-22.

The purpose of this paper is to discuss some of the issues in developing the capacity to conduct economic impact analyses of natural or human-induced climate change. The author argues that some special features of climate change require substantial amendments to, or indeed complete replacement of, these traditional impact analysis methodologies (e.g., input-output and computable general equilibrium). However, it is understood that the social science tools necessary to address all the complex issues associated with climate change are not yet available. That is, the author realizes that we do not have two important ingredients for making progress with these questions: a sufficient community of social scientists with knowledge of climatic systems to appreciate the problem of economic impact analyses for climate change; and an accumulated set of research information directed toward evaluating the implications of climate for economic activities and social structures. "As a consequence," the author elaborates, "in considering the prospects for the development of a capacity to perform economic impact analyses of changes or variations in climate we must address both issues purely associated with economic methodology and those of an institutional nature pertaining to the development of a social science research community in this area." This paper focuses primarily on the methodological issues.

Sonka, S.T.; Lamb, P.J. 1987. On climate change and economic analysis. Clim. Change 11:291-311.

This article is a clear discussion of analytical approaches to climate change. In the authors' view, economic analysis would have much to contribute to society's understanding of the importance of climate change. Yet, they believe, the contributions of prior analyses have been limited. To gain more useful insights for decision making, they suggest a change in approaches from evaluating the effects of a changed climate to evaluating the effects of currently changing climate. Linking physical and economic models of differing levels of aggregation is the approach the authors recommend for analyzing changing climatic conditions.

Spash, C.L. 1994. Double CO_2 and beyond: benefits, costs, and compensation. Ecol. Econ. 10:27-36.

The author argues that basic cost-benefit analyses are irrelevant for attributing intertemporal weights to social welfare changes as a result of climate change. He attempts to refute the contention that the present generation need not be concerned over loss or injury caused to future generations, because the latter will benefit from advances in technology, investments in both manufactured and natural capital, and direct bequests.

Tol, R.S.J. 1996. The damage costs of climate change: towards a dynamic representation. Ecol. Econ. 19(1):67-90.

The purpose of the paper is to "attempt" to express climate change as a function of changes in both climate and socioeconomic conditions. The subject areas discussed with respect to climate change are level versus rate of change, speed of adaptation, speed of restoration and value adjustment, and symmetry. Those considered with respect to socioeconomic change are agriculture, migration, and the valuation of intangible losses. Uncertainty and higher-order impacts are treated briefly. The author argues qualitatively and quantitatively that the issues discussed in this paper matter a great deal for the damage profile over the next century.

van Kooten, G.C. 1990. Climate change impacts on forestry: economic issues. Can. J. Agric. Econ. 38:701-710.

The focus of this paper is carbon dioxide, because of its importance in plant growth and because trees have an important socially desirable function of removing the gas from the atmosphere (a process called sequestration). The author argues that efficient mitigation strategies often require conversion of agricultural land to forestry to sequester carbon, but such strategies could be wrong for Canada's boreal forest region, if global warming is inevitable. He concludes that from both economic and social perspectives, conversion of the southern boreal forest to grassland or agriculture might be a better policy.

van Kooten, G.C. 1995. Climatic change and Canada's boreal forest: socio-economic issues and implications for land use. Can. J. Agric. Econ. 43:133-148.

Describing the positive direct effect of carbon dioxide enrichment in increasing photosynthesis and its indirect effect in increasing temperatures that promote tree growth, the author argues that an increased incidence of pests and forest fires and the possibility of moisture stress might in fact more than offset the benefits. Concentrating only on the benefits of predicted responses of tree growth to the climatic changes resulting from doubled concentrations of carbon dioxide, the author uses methods developed in applied welfare economics to determine the economic effects of climate change. On the basis of results obtained from general circulation models he developed for two climate scenarios, the author concludes that forest productivity increases under both scenarios, but benefits accrue primarily to Canada's trading partners.

van Kooten, G.C.; Arthur, L.M. 1989. Assessing economic benefits of climate change on Canada's boreal forest. Can. J. For. Res. 19(4):463-470.

The authors start from the premise that the correct method for measuring the benefits of climate change is to compare the present value of economic surpluses under different climatic conditions in a dynamic context. This is the so-called with-and-without principle of cost-benefit analysis. However, the authors conclude that it is a difficult task to determine whether or not the welfare effects of climate change are positive or negative in the context of the forest sector. This is because several empirical studies in Canada and elsewhere appeared to report that forest site productivity increases with increased concentration of carbon dioxide. Although their experiment did not produce conclusive results, the authors caution that further multidisciplinary research and greater effort to educate lay persons about various concepts, such as opportunity cost, are required.

Yohe, G.; Neumann, J.; Marshall, P.; Ameden, H. 1996. The economic cost of greenhouse-induced sea-level rise for developed property in the United States. Clim. Change 32(4):387-410.

The authors attempt to provide "economic cost" estimates that might be attributed to greenhouse-gas-induced rises in sea level on the developed coastline of the USA. For example, for a transient trajectory along a 50-cm sea level, the authors predict the costs attributable to greenhouse effects to be US$70 million per annum by the year 2065. However, the credibility of the author's methodology is questionable. It is based on the subjectively determined (estimated) opportunity costs of abandoning developed coastal properties and maximization of the roughly estimated net benefits (i.e., gross benefits minus opportunity costs) of protecting shorelines.

Fire Management

Although forest fire remains a major area of concern for the CFS, an extensive search revealed that not much research has been conducted on the socioeconomic effects of forest fire. This section is an addition to the report of Beverly and Williamson (1994), which annotates 26 papers; that report itself is annotated below. By all measures, a lot of research remains to be done on the socioeconomics of forest fire management.

Bellinger, M.D.; Kaiser, H.F.; Harrison, H.A. 1983. Economic efficiency of fire management on nonfederal forest and range lands. J. For. 81(6):373-375.

Using the cost plus net value change criterion, the authors found that fire protection measures taken on nonfederal and rangelands were cost effective. However, to increase the efficiency of fire protection, they recommend increasing protection in zones with high timber values and decreasing protection in zones with low timber values. They argue that this strategy would keep fire protection costs the same while reducing losses due to fires by 48%.

Beverly, J.; Williamson, T. 1994. Wildland fire management economics: post 1982 literature review and bibliography [working paper]. Nat. Resour. Can., Can. For. Serv., Policy, Econ. Int. Aff., Hull, QC.

The authors present a general overview of recent research related to forest fire economics and decision support systems. After providing a brief historical background, they highlight simulation modeling and operations research techniques used in fire management decision making. This is followed by an annotated bibliography of 26 recent papers dealing with the economic analysis of wildfire.

Boychuk, D.; Martell, D.L. 1996. A multistage stochastic programming model for sustainable forest-level timber supply under risk of fire. For. Sci. 42(1):10-26.

This article looks at the effect of fire loss on timber supply at the forest level. Three objectives of the study were to develop forest-level planning models to evaluate the impact of fire loss on timber supply; to apply these models with hypothetical data to determine how other factors affect the impact of fire loss on timber supply; and to explain conflicting results in the literature. The authors conclude that to produce a stable timber supply, a buffer stock of timber is required, which would increase the expected long-term harvest quantity. The results were sensitive to the method of managing timber production.

Brown, T.C.; Boster, R.S. 1978. On the economics of timber damage appraisal for public forests. J. For. 76(12):777-780.

Acknowledging that appraisal is the basis for fire-suppression decisions, the authors provide various reasons for how and why appraisals are important. Where timber is managed for production of maximum site rent, they contend that appraisal is rather straightforward: it is a matter of applying standard financial criteria in a with-and-without procedure. Where the aim is maximum mean annual increment, however, the procedure may yield seemingly incongruous results: if the goals and constraints guiding management allow prorating a loss by substituting one part of the inventory for another, the value of the damage may be less than the value of the specific resource in the absence of the damage. This is a consequence, they argue, of maximizing wood rather than value. They caution that ignoring the "with-and-without" approach in public decision making might result in over-expenditure for fire suppression.

Englin, J.; Boxall, P.C.; Chakraborty, K.; Watson, D.O. 1996. Valuing the impacts of forest fires on backcountry forest recreation. For. Sci. 42(4):450-455.

The authors developed a discrete-choice travel cost model for backcountry forest recreation, using 2 years of backcountry canoe registrations from Nopiming Park, Manitoba. They found that the amount of forest along the route that had been burned in the previous 10 years was a statistically significant explanatory variable for the choice of route. The welfare loss from fires that occurred in 1983 was estimated using a discrete-choice travel cost model, combined with a count model of trip demand. In addition, the authors estimate a linear intergenerational damage function for one of the fires and include the present value of damages under alternative discount rate assumptions.

Martell, D.L. 1994. The impact of fire on timber supply in Ontario. For. Chron. 70(2):164-173.

Using historical reports of fire, the author developed a forest-level timber harvest scheduling model and used it to show how such a model can be employed to assess the implications of fire management regimes for timber supply. He concludes that, although fire might have had a significant detrimental impact on timber supply in some parts of northwestern Ontario during the 1976-1988 period, the effectiveness of the province's forest fire management system was such that timber supply in most districts was not significantly dim-inished by fire.

McKetta, C.W.; González-Cabán, A. 1985. Economic costs of fire-suppression forces. J. For. 83(7):429-432.

The author estimated the costs of fire management inputs for presuppression and large fire suppression. He found significant

hourly cost differences by deployment status among 12 units – ranging from small engines to 20-person hand crews – in three western states and three United States Department of Agriculture Forest Service regions. His estimated suppression costs were 32% to 138% higher than the then-current planning figures. Overhead, training, facilities, and equipment were major sources of variation.

Mills, T.J.; Flowers, P.J. 1985. Fire-induced changes in net value of timber: a sensitivity analysis. Can. J. For. Res. 15(5):973-981.

This paper documents the pattern of "fire situations" in the northern Rocky Mountains of the USA and analyzes its economic impacts. The authors describe a "fire situation" as the fire site, fire severity, and timber management characteristics of a fire. They developed a hypothetical "fire situation" as a combination of these characteristics and conducted financial and economic analyses. The change in timber's present net value as a result of wildfire was estimated for 108 hypothetical "fire situations." They found that net value changes, estimated by simulating timber yield changes on the fire site only, ranged from a loss of $2382 to a gain of $4191 per ha burned. The authors report that the magnitude and sign of the net value changes were related to the fire size, fire severity, and timber management characteristics of the "fire situation."

Reed, W.J.; Errico, D. 1985. Assessing the long-run yield of a forest stand subject to the risk of fire. Can. J. For. Res. 15(4):680-687.

Using previous empirical results, the authors developed "fire-adjusted, volume-rotation" curves for graphically determining optimal rotation age and long-run yield in the presence of fire risk. For white spruce of the northern interior of British Columbia, they show that even modest rates of fire can result in very large reductions in long-run yield and land expectation value.

Rideout, D.B.; Omi, P.N. 1990. Alternate expressions for the economic theory of forest fire management. For. Sci. 36(3):614-624.

The authors compare two traditional economic efficiency criteria, minimization of cost plus net value change versus profit maximization, in terms of the insights provided into fire management decisions. They also examine the historical rationale for favoring minimization over maximization. They conclude that there are advantages to formulating the problem in terms of profit maximization. These include explicit attention to production relations and explicit treatment of revenue and objective functions.

Sohngen, B.L.; Haynes, R.W. 1997. The potential for increasing carbon storage in United States unreserved timberlands by reducing forest fire frequency: an economic and ecological analysis. Clim. Change 35(2):179-197.

To determine if a reduction in forest fire frequency would increase projected storage of carbon in United States forests, the authors linked the impact of fire damage on forests with an economic model of the forest sector in the USA. They conclude that changes in inventory levels could be used to project both the amount of carbon stored and an economic response and also that if fire frequency was reduced from the level that prevailed during the research, carbon storage could be increased in unreserved US timberlands over the period 1990 to 2040.

van Wagner, C.E. 1979. The economic impact of individual fires on the whole forest. For. Chron. 55(2):47-50.

The author describes a technique for assessing the economic impacts of forest fire on an entire area of a forest under a specific management regime. He suggests that a change in present value of the whole forest as a result of a fire incident is a better measure of loss than the present value of the burned area only, because the impact is diffused throughout the forest.